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Competing Arbitrary and Non-Arbitrary Stimulus Relations in Adults, Normally Developing Children and Children with a Diagnosis of Autism

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Abstract

The current thesis sought to extend the work of Stewart, Barnes-Holmes, Roche, and Smeets (2002) who reported that competing non-arbitrary stimulus relations disrupted equivalence-consistent responding in adult humans. Chapter 1 provides a review of research into stimulus equivalence, derived relational responding, and notes that the Colour-Test condition presented in the Stewart et al. (2002) study shared many features of tests traditionally used to measure executive function (EF). An introduction is also provided to cognitive theories of EF.

The study presented in Chapter 2 provides support for Stewart et al. (2002) and reports that participants who were trained with black stimuli but tested with coloured stimuli showed lower levels of equivalence-consistent responding relative to other groups. Results also showed that while training with coloured stimuli is effective in undermining colour as a source of non-arbitrary stimulus control, exemplar training with black stimuli is shown not to be effective in undermining non-arbitrary stimulus control across stimulus sets. However, when exemplar training is combined with colour training participants produced the highest levels of equivalence-consistent responding

Chapter 3 reports a study in which normally developing young children were presented with a table top match-to-sample training and testing procedure modified to make it appropriate to the abilities of this younger population. The modifications required participants to demonstrate criterion levels of equivalence with familiar stimuli and with novel stimuli coloured black prior to the introduction of a competing colour relation. All participants readily demonstrated equivalence-consistent responding with black stimuli and, critically, maintained equivalence when a competing colour relation was introduced.

Chapter 4 presents two studies using a participant population of young children diagnosed with autism. Study 1 employed a reduced training and testing procedure but the participant failed to demonstrate equivalence class formation in any test condition. However, when six participants diagnosed with autism were subsequently exposed to the full training and testing procedures in Study 2, all six participants demonstrate equivalence-class formation with black stimuli. Critically, five of the six participants failed to maintain equivalence when a competing colour relation was introduced during testing, showing clear disruption from the competing colour relation.

Chapter 5 presents a number of studies that sought to determine if training with coloured stimuli would remediate the disruption of equivalence observed for the five participants who completed Study 2 reported in Chapter 4. Study 1 demonstrated that colour training was effective in undermining non-arbitrary stimulus control within the same stimulus set for all participants. Subsequent studies showed that all participants maintained equivalence-consistent responding in the presence of competing colour relations across new sets of novel stimuli.

Chapter 6 then describes two studies that sought to determine if undermining colour as a source of non-arbitrary stimulus control would also facilitate participants in maintaining equivalence in the presence of other sources of competing non-arbitrary stimulus control. Study 1 showed that participants successfully maintained equivalence-consistent responding when a competing shape relation was introduced and Study 2 showed that two participants also maintained equivalence when both shape and colour relations were simultaneously introduced during testing.

The studies presented in Chapter 7 employed two experimentally naïve participants and demonstrated that competing shape relations disrupted equivalence class formation when introduced during testing. Subsequent studies showed that shape training was effective in undermining shape as a source of non-arbitrary stimulus control and participants maintained equivalence when a competing colour relation was subsequently introduced.

Chapter 8 provides a summary of the findings in the current research programme and considers a number of methodological and conceptual issues arising from the studies, identifying possible weaknesses and questions that could be targeted in future research. The relationship between the current research and the cognitive concept of EF is also considered and clarified. Finally, it is concluded that further research into competing non-arbitrary stimulus control over derived relational responding may be important in understanding and treating deficits associated with autism.

General Introduction

CHAPTER 1

Executive Function: A Review

The term executive function (EF) is used to describe a range of poorly defined processes that are putatively involved in such activities as “problem solving” (Levin, Goldstein, Williams & Eisenberg, 1991), “planning” (Shallice, 1982), “initiation” of activity (Burgess & Shallice, 1996c), “cognitive estimation” (Shallice & Evans, 1978) and “prospective memory” (Cockburn, 1995). In addition, EF processes have been linked to the range of symptoms associated with lesions to the frontal lobe of the brain, traditionally known as “frontal lobe syndrome”. However, early attempts by neuro-psychological researchers to link EF capabilities to particular brain systems were inconclusive (Reitan & Wolfson, 1994).

Cognitive psychology has tended to focus its attention on the less complex facets of human cognition, and up until recently very little investigation had been conducted on EF. Early descriptions of EF impairments are strikingly similar to definitions of “willed”, “purposive” or “voluntary” behaviour used by philosophers and theologians. Even more contemporary definitions of EF employ language from “common sense” or “lay” usages to describe specific functions involved in the solution of tasks. As a result, it has passed largely unrecognised that hypothetical components of EF behaviour such as “planning”, “monitoring”, “control” and “inhibition” are simply descriptions of task demands (Rabbitt, 1997), and thus these terms remain ill-defined, at the level of psychological or behavioural process. In order to move beyond the use of “everyday language” terminology with reference to EF it may be useful to examine the difference behaviourally between EF and non-EF functions. The primary purpose of this doctoral thesis is to provide the beginnings of such an analysis both conceptually and empirically.

Traditional EF Definitions and Research

EF research has been based largely on a seminal study, in the cognitive tradition, that investigated what were called *controlled* and *automatic* processes in problem solving behaviour (Schiffen & Schneider, 1977). This early study showed that when individuals first encounter a novel task that demands they discriminate between two different sets of symbols or words, their decision times become slower as the number of items in each response class increases. Insofar as the participant has no prior practice with a novel task (by definition) he or she is forced to process much more than the theoretical minimum amount of information that is needed in order to make the required discriminations. According to cognitive theory, this then places a strain on the system capacity of the individual, slowing down their responses on the EF tasks and indeed on any other tasks in which they may be engaged at the same time.

As practice of the task increases the behaviour becomes more automatic to the individual and the amount of information that must be processed in order to make discrimination is reduced. As a result, more automated tasks can often be carried out simultaneously without interfering with each other. However, in order for optimisation of dual task performance the two tasks must be practiced together and not separately. According to Schiffen and Schneider, the advantage gained in speed comes at the cost of flexibility, in that as the task becomes more automated it is less consciously controlled and thus does not generalise from one task to another. Indeed, it may be so task specific that even trivial alterations to task demands result in an abrupt regression to "controlled" behaviour with the consequent loss in speed and accuracy. Schiffen and Schneider also concluded from their research that when task demands are varied during the practice stage, even to a small degree, then automaticity of performance is never attained.

Schiffen and Schneider's (1977) work on controlled and automatic processing has been used as a basis for cognitive researchers to assess the differences between EF and non-EF processing. Executive control it is argued, is necessary to deal with novel tasks that require us to formulate a goal, to comprehend these plans with regard to their probable rate of success and efficiency, to initiate the plan selected and to carry it through, amending it as necessary, until it is successful or until impending failure is recognised (Rabbitt, 1997). The key difference, however, is not only that EF behaviours are more complex than non-EF behaviours but that EF behaviour requires the individual to recognise, evaluate and choose among a variety of alternative courses of action. A non-EF task will involve a single effective behavioural sequence that has been already identified and practiced, and is to be carried out without the need to propose and evaluate alternatives (Rabbitt, 1997). Non-EF behaviour tends to be initiated by changes in the environmental input; EF behaviour on the other hand can be initiated and controlled independently of environmental input. Adaptive flexibility is a characteristic of EF behaviour and this allows the individual to react when the environment does not behave in the manner expected at the outset and no guidance is available from experience.

According to cognitive theory, EF behaviours are necessary to initiate new sequences of behaviour and also to interrupt other ongoing sequences of responses in order to do so. Executive processes are also hypothesised to suppress or inhibit automatic and habitual responding, replacing it with task appropriate responding (Lowe & Rabbitt, 1997). In theory, EF allocates the attentional control to more than one input in order to allow a variety of different demands to be met simultaneously (Rabbitt, 1997). Cognitive research has shown that individuals with executive dysfunction display contextually inappropriate responses (Shallice & Evans, 1978; Parkin, 1997). For example, such dysfunction appears to disrupt the individual's ability to judge when an intention, as well as the responses that result, are implausible or unacceptable in a particular context.

Cognitive researchers have also argued that when carrying out problem solving behaviour EF is required to assess the progress of the strategy implemented in order to detect and correct errors, to alter plans when success becomes unlikely, and assess the situation in order to recognise opportunities for new and more desirable goals. EF also allows the individual to formulate, select among, initiate, and execute new plans to attain the desired goal. Even very complex non-EF behaviour, according to cognitive research, does not seem to be monitored in this way (Rabbitt, 1997). Moreover, the EF assessment of the individual's goal directed behaviour may be sustained over a long period of time (Manley & Robertson, 1997), and this allows the individual to predict the outcomes of long and perhaps complex series of events. Individuals with executive dysfunction often demonstrate behaviours that could be described as "goal neglect" when faced with novel tasks in which they are required either to switch from one pattern of responding to another, or to maintain the present pattern of responding in the face of other changes to the task (Duncan, 1995). In effect, there appears to be a deficit in holding intended sequences of action in the mind over long periods of time so as to carry them out when circumstances demand it (Einstein & McDaniel, 1990).

Cognitive researchers have also suggested that EF consists of a number of interconnected control processes (Phillips, 1997) each of which is drawn upon to differing degrees by different demand contexts. In this regard, Norman and Shallice (1980) outlined five types of situation where routine, automatic activation of behaviour (non-EF) would not be sufficient for optimal performance. These include situations that involve planning or decision making; those involving error correction or troubleshooting; situations where responses are not well learned or contain novel sequences of actions; dangerous or technically difficult situations; and situations that require the overcoming of a strong habitual response or resisting temptation. According to this view, therefore, in order for tests of EF performance to have face value they must involve some combination of novelty, effortfulness and working memory demands.

Test of Executive Function

The measure of EF is an urgent issue with relation to a number of applied fields, including children's development of EF (Denckla, 1994), declines in EF with adult age (Baddeley, 1986), and deficits in EF in patients with Clinical conditions such as autism (McEvoy, Rogers, & Pennington, 1993), and Alzheimer's disease (Della Salla, Logie, Spinnler, 1992). Due to the broadness of the behaviours to be measured there are a multitude of different tests professing to measure EF. As behavioural phenomena these tests are inherently more specific than much of the descriptive terms used to describe EF.

In studies that use a normative population, EF is often studied experimentally by examining interference between concurrent tasks (e.g. Baddeley, 1986; Gilhooley, et al., 1993). In this paradigm, a target task is performed simultaneously with a secondary task that is thought to load EF. If the simultaneous performance of the secondary task substantially interferes with performance on the target task, then this latter task is deemed to involve EF (Logie, et. al. 1994). There are a number of advantages to the dual task method of assessing EF. It can be used to determine if executive components are involved in a variety of different tasks, as well as offering the possibility that different types of secondary tasks might be used to tap different aspects of EF. Finally, it offers the possibility that EF tasks may be dissociated from non-EF tasks or purely visio-spatial components of the task environment (Phillips, 1997).

On balance, there are also drawbacks involved with the use of dual task assessments of EF performance. By their very nature, dual task assessments of EF are effortful, unpleasant, challenging and stressful, (Phillips, 1997). Participants may well become de-motivated, which would confound the results of the task (i.e., a poor performance might reflect lack of effort rather than an inherent limitation in the cognitive system). Another drawback with dual task tests of EF is that it is difficult to control for adult participants' pre-experimental histories with regard to the tasks used. Different participants may have differing degrees of past exposure to the broad types of tasks being used, which may confound their results relative to each other. Research has shown that practice using one set of stimuli may also have a practice effect on different stimuli when they are presented in a similar task context (Rabbitt, 1997). This practice effect may also serve to negate the effectiveness of the dual task assessment with regard to EF processes. In the presence of a confounding practice effect the dual task assessment may thus reflect, to some degree, non-EF processes (e.g., level of experience with the type of task employed).

Another test, or group of tests, that are used to assess EF are referred to as Frontal lobe tests. Many of these tasks contain a competing "proponent response" that interferes with the experimentally established "correct" response. Proponent responses "are erroneous responses that are called out" either by some salient feature of the environment or by some features rendered salient through previous learning" (Biro & Russell, 2001 pp. 98). The Stroop test is a classic example (Stroop, 1935). In this task, participants are required to name the physical colour of a succession of colour-name words (e.g., 'blue') that are each printed in a different colour from that to which they refer (e.g., 'blue' printed in red). Participants have a tendency to state the colour-name rather than to name the actual colour, and this is especially the case for those who demonstrate weak EF. According to a cognitive interpretation, the participant must inhibit their normal tendency to attend to the word they are reading rather than the colour of the ink. Thus, this test measures the participant's ability to inhibit ineffective responding.

The Wisconsin Card Sorting Test (Anderson, Damasio, Jones, & Tranel, 1991) provides another example of a methodology that is used to assess EF. This task presents participants with four cards varying in colour, shape, and number, which are placed in front of the participant. Next, the participant is given two decks of cards and is asked to match the cards in the deck with one of the four "key" cards. After the response, an experimenter informs the participant whether the cards have been sorted correctly or not. As the participant masters a matching rule to a criterion level, the experimenter changes the matching rule without informing the participant. In this case the participant now receives negative feedback for responses that had previously gained them positive feedback. Participants with poor EF often show more perseverative responding than would control group participants (Ozonoff, Pennington, & Rogers, 1991).

Yet another task is The Tower of Hanoi, which is thought to assess a participant's ability to inhibit a previously learned response that is irrelevant in the present situation. A board is presented with three vertical pegs. On the right hand peg a set of disks are arranged to form a tower, with smaller disks resting on top of larger disks. The participant must plan and execute a sequence of moves that transform the configuration of disks to a configuration that is identical to the experimenters without placing a larger disk on top of smaller disks. Doing so requires that the participant refrain from engaging in the "obvious" solution, which would involve piling larger disks on top of smaller disks in order to create the final tower.

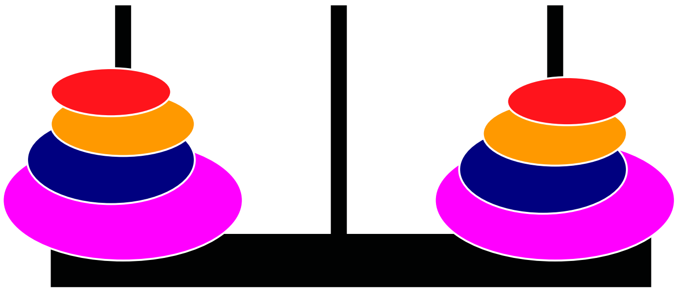

Figure 1. Tower of Hanoi

A Behaviour-Analytic Approach to Executive Function

As stated previously, each of the foregoing tasks are often referred to as Frontal Lobe tests and involve novel problems that, according to cognitive theory, require effort in terms of online monitoring or response inhibition, and usually make demands on working memory (Phillips, 1997). Poor performance on these tests is widely taken as showing a deficit in EF. However, there are a number of problems with the assumption that these tests measure EF. First, not all researchers accept that the major function of the frontal lobes is EF processing (Damasio, 1994; Reitan & Wolfson, 1994). Indeed, there have been frequent findings concerning patients with frontal lobe damage that perform well on such tests (e.g. Shallice & Burgess, 1991a), and patients with non-frontal lesions who perform poorly on the same tests that are supposedly frontal lobe specific (Anderson, Damasio, Jones, & Tranel, 1991). These research results highlight a lack of clarity with respect to the concept of EF and also its neuro-cognitive source.

From a behavioural perspective, there are a number of potential reasons why a participant may perform poorly on any of the frontal lobe tests rather than simply a deficit in EF (which itself remains ill-defined). However, research in this area within the behavioural tradition has been virtually non-existent. Only recently, for example, have behavioural researchers attempted to develop dual task methodologies that may provide a means of measuring the types of behavioural processes involved in what cognitive researchers call EF (e.g., Stewart, Barnes-Holmes, Roche, & Smeets, 2002).

The behavioural approach views psychology as the study of the interaction between the whole organism and its historical and current environments and seeks to avoid reification. A research tradition has developed in contemporary behaviour analysis that is prepared to examine complex human behaviour from a behaviour analytic point of view (for several recent book length reviews of that literature see Hayes, 1989; Hayes & Chase, 1991; Hayes & Hayes, 1992a; Hayes, Hayes, Sato, & Ono, 1994). Behaviour analysts in this area are especially focused on verbal behaviour. From a behaviour-analytic viewpoint, EF is seen as a subset of rule governed behaviour (Hayes, Gifford, & Ruckstuhl, 1996), and there is an empirical body of research literature focused on analysing the development of rule governed behaviour through the examination of derived stimulus relations, and it is to this issue we now turn.

Stimulus Equivalence

Sidman (1971) first examined the phenomenon of stimulus equivalence using systematic behaviour analytic methodologies in an attempt to devise improved methods for teaching reading comprehension. His seminal study examined the emergence of untrained, or derived, associations between stimuli using a developmentally disabled participant. The participant was trained to match spoken words to pictures and spoken to printed words but then subsequently matched printed words to pictures without additional training. These untrained responses are now often referred to as derived stimulus relations because they emerge in the absence of explicit training. The specific derived relations observed in Sidman's study were labelled equivalence classes, and this label is still used today by most researchers.

Investigations of stimulus equivalence are, in the main, conducted employing a match to sample experimental context, using either a computer-based presentation or tabletop procedures. Both preparations involve the simultaneous presentation of three or more arbitrary stimuli, one of which acts as a sample stimulus (e.g. A1) and the remaining two as comparisons. Typically, the comparison stimuli are at the bottom of the table or screen (e.g. B1 and B2) and one of them correctly "goes with" the sample. Abstract shapes or syllables that share no formal features are often used as stimuli and what constitutes the "correct" A-B matching response is almost always entirely arbitrary, in that the experimenter "arbitrarily" designates which comparison "goes with" which sample.

Sidman conducted a series of additional studies through the course of the 1970's and further refined the concept of stimulus equivalence (see Sidman, 1994, for a review). He argued that the phenomenon of stimulus equivalence involved three distinct features: reflexivity, symmetry and transitivity (Sidman, 1986). Reflexivity is defined as generalised identity matching involving the consistent matching of a stimulus to itself in the absence of reinforcement or explicit instruction. In other words, reflexivity is identity matching. If given a stimulus A1 and presented with an array of stimuli, the subject will pick stimulus A1 from the array.

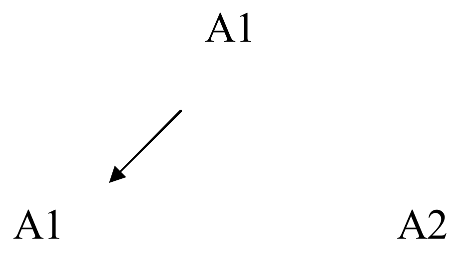

Figure 2. Reflexivity

The property of symmetry is defined as the functional reversibility of the conditional relation. If the person learns to pick B1 from an array of stimuli, given A1 as a sample, the stimulus A1 will now be picked from an array given the stimulus B1 as a sample without direct reinforcement for doing so.

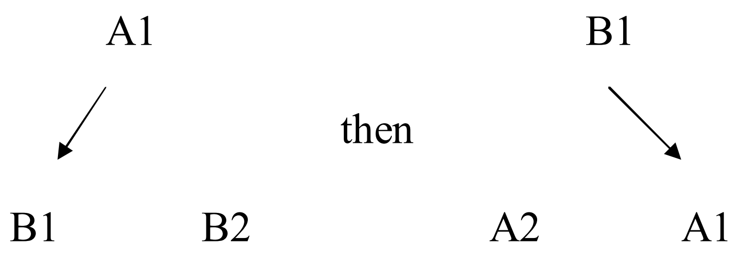

Figure 3. Symmetry

Transitivity refers to the combination of relationships and involves the presence of three or more stimuli. For example, if a subject is explicitly trained in A1-B1 and B1-C1 relations, then the transitive relational response A1-C1 will be demonstrated without additional training (See figure 4 for representation).

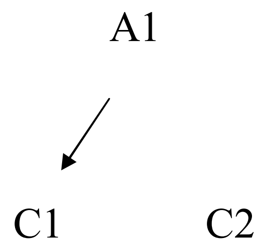

Figure 4. Transitivity

There are a further set of derived stimulus relations that may otherwise be referred to as symmetric-transitive relations, or equivalence relations. If a subject is trained in the relations A1-B1 and B1-C1, then the untrained relation C1-A1 may be readily derived in the absence of feedback. The presence of these untaught, or derived stimulus relations, has been taken by behaviour analysts as demonstrating that A1, B1 and C1 are participating in an equivalence class. This is a class of mutually substitutable elements (Barnes, Brown, Smeets & Roche, 1995).

Behavioural research has shown that it is possible for both non-humans and humans to demonstrate control by stimulus relations when such relations are based on the formal properties of the related events. For example, animals may be taught to discriminate relationships such as brighter or dimmer, (Reese, 1968), in which the non-arbitrary features of the environment specify the relationship between the stimuli. The phenomenon of stimulus equivalence, and its related effects, indicates that language-able humans also have the ability to show the abstraction of such non-arbitrary relational responding, in that it comes under the control of arbitrary contextual cues available in the environment. In other words, the stimuli involved in the relation are related to each others based on a history of conventional training in derived relations, regardless of the non-arbitrary form of the related events, (Hayes, Gifford & Ruckstuhl, 1996). For example, there is nothing in the form of the written word "car" that would allow the formation of a non-arbitrary relation to an actual car. The two stimuli are related together because of a history of reinforcement for derived relational responding, not because the word and the object are physically similar.

The phenomenon of stimulus equivalence appears to be directly relevant to the development of language in humans. Studies have shown that derived stimulus relations are correlated with verbal performance and that it develops over time, much like early language development (Lipkens, Hayes & Hayes, 1993). Furthermore, a strong formal resemblance appears to exist between equivalence performances and the bi-directionality that characterises word-referent relations (Hayes, Blackledge & Barnes-Holmes 2001), and this seems to suggest a new model for understanding semantic relations (Sidman & Tailby, 1982). Consider, for example, that during normal language acquisition a child will often be taught word-object relations that are both symmetrical and transitive. If a child of sufficient verbal abilities is shown the word "car", for instance, and taught to select a picture of a car from an array of different photos, the child would later be expected to select the word "car" from an array of different words when shown a picture of a car, without training to do so. This demonstrates a symmetrical relation. Transitive relations are also commonplace in early language training and several studies have used these types of naming tasks to demonstrate the formation of equivalence classes (Dixon & Spradlin, 1976; Sidman, 1971). This suggests that derived stimulus relations are a central defining feature of verbal events and that verbal regulation is based on these derived stimulus relations.

Although there is a wealth of research that has focused specifically on derived stimulus relations, other non-equivalent derived relations including different, more-than/less-than, and so on, have also been studied (Barnes & Keenan, 1993; Dymond

& Barnes, 1995; 1996; Roche & Barnes, 1996, 1997; Roche, Barnes-Holmes, Smeets, Barnes-Holmes, & McGeady, 2000; Steele & Hayes, 1991). The experimental analysis of these relations suggest that if relating itself can be learned and brought under contextual control, a wide variety of relational responses seem possible. Due to the complexity of these derived relations, and the differences in the patterns of responding they demonstrate, Sidman's properties of equivalence do not appear to provide a generic nomenclature for these events. For example, take the relation of "smaller than". If A is smaller than B, it does not follow that B is also smaller than A. The relation between the stimuli is not symmetrical, and thus the stimuli do not meet the criteria necessary to be categorised as participating in an equivalence class. The complex patterns inherent in these types of non-equivalence relations are more readily accommodated in an alternative account known as Relational Frame Theory (RFT) (Hayes, Barnes-Holmes, & Roche, 2001).

Relational Frame Theory

RFT proposes that when language-able humans receive prolonged exposure to certain contingencies of reinforcement operating within a verbal community they will demonstrate responding based on derived or arbitrarily applicable relations (Hayes, Gifford, & Ruckstuhl, 1996). These relations are defined not by the physical properties of the relata per se, but by additional contextual cues (Hayes, Barnes-Holmes, & Roche, 2001; Hayes, 1991). According to RFT, these relations are referred to as relational frames and can involve any stimuli or event and have an unlimited variety of response topographies. Again let us refer to the example of the young child being taught bi-directional name-referent relations. The child may initially be taught the equivalence class of "car" containing the vocal label, the written word and a picture of a "car". As the child gains more language his/her vocabulary of name referent relations may become greatly increased and in a sense the child learns the form of language acquisition itself. In other words, with enough instances of bi-directional name-referent relations trained in both directions, the relational response becomes sufficiently abstracted to operate as an overarching class containing virtually any name-referent relation (Hayes, Barnes-Holmes, & Roche, 2001). Because the form of the related stimuli will vary widely, contextual cues in the environment control the application of the relational responses involved in any specific instance. For example, name-referent relations may be controlled by contextual cues such as, *this is a* ___, or *look at this* ____, and so on. Paralinguistic cues, such as the speaker's eye gaze may also function in a similar way. Indeed, the formation of equivalence relations in the behavioural laboratory may be subject to functionally similar forms of contextual control. The matching-to-sample format is likely familiar to most children and adults and may well serve as a contextual cue for equivalence responding, especially when appropriate instructions are also used (e.g., "This [comparison] goes with this [sample]).

The concept of the contextually controlled overarching relational frame leads to a much broader range of phenomena than would emerge from trained relational responding alone. Furthermore, in many cases the relational phenomena are more general than equivalence and they may not result in classes of stimuli -- the stimuli instead form a relation. A psychological relation exists if the stimulus function of one event depends upon the stimulus functions of another event (Hayes, 1994). Several studies have demonstrated that not just equivalence relations, but a wide variety of relational networks emerge in arbitrary matching to sample training if the subjects are given pre-training with cues that control other forms of relational responding (Dymond & Barnes, 1994; Steele & Hayes, 1991; Barnes & Keenan, 1993). RFT has adopted terminology, therefore, that is generic and applicable to all possible derived stimulus relations. There are three behavioural functions that characterise the processes of relational framing.

The first is mutual entailment, which states that if in a given context A is directly related to B, then, in that context, a derived relation between B and A is mutually entailed. If trained to choose B in the presence of A, then the untrained relation of choosing A in the presence of B will emerge. The second is combinatorial entailment which holds that in a given context if A is directly related to B, and B is directly related to C, then, in that context, a derived relation between A and C is entailed (based on the combination of the A-B and B-C relations). The third characteristic is transformation of stimulus function. Imagine, for instance, that there is a mutual relation between stimulus A and stimulus B, and A has some additional psychological function, then, in a context that selects that function as relevant, the stimulus function of B may be transformed consistent with its relation to A (Hayes, 1994). In summary, therefore, a relational frame is a relational response that is not based solely on the direct non-relational training with regard to the particular target stimuli. Neither is it based solely on the non-arbitrary characteristics of either the stimuli or the relation between them (Hayes, 1994). Instead, relational responding depends primarily on contextual cues that are established and maintained through ongoing behavioural interactions with the wider verbal community.

The Role of Exemplar Training

From an RFT perspective arbitrarily applicable relational responding is established through a relevant history of reinforcement across exemplars (Barnes, 1994, 1996; Barnes & Holmes, 1991b; Barnes & Roche, 1996; Hayes, 1991, 1994). A recent study suggested a procedure for using exemplar training to establish derived relations in a participant population of children aged between four and five years (Barnes-Holmes, Barnes-Holmes, Roche, & Smeets, 2001). The study investigated whether exemplar training would readily facilitate transformations of function in accordance with symmetry across four experimental phases. In the basic procedure participants were trained in an action-object conditional discrimination and were then tested for derived object-action symmetry relations. For example, during training the experimenter touched his nose, then choosing the toy bicycle was reinforced (the trained relation was touch nose-bicycle), and when the experimenter waved choosing the cow picture was reinforced (the relation was wave-cow).

Participants were then exposed to test trials in which they were required to derive object-action symmetry relations. For example, when the experimenter presented a cow the participant was required to wave (i.e. the tested relation was cow-wave). Across subsequent sessions a multiple-baseline design was employed to introduce exemplar training (in the form of explicit symmetry training) for subjects who failed the symmetry test. Across Experiments 1 and 2, none of the eight subjects demonstrated derived symmetrical responding prior to receiving explicit symmetry training. Simply pre-training object-action responding in Experiment 3 appeared to facilitate symmetry, but only for four of the eight participants. Symmetry emerged for the remaining four participants who failed only after exposure to exemplar training. This study was one of the first to provide empirical evidence for the efficacy of exemplar training in establishing derived stimulus relations.

On balance, a closer examination of the results of this study (Barnes-Holmes, Barnes-Holmes, Roche, & Smeets, 2001) revealed that only a very limited number of exemplars were required in order for the participants to demonstrate derived responding in the context of the object-action tasks. This suggests that the exemplar training simply activated a previously established relational repertoire rather than demonstrating the efficacy of multiple exemplar training procedures in establishing ab initio a relational framing repertoire.

A more recent study examined the use of a multiple exemplar training procedure to establish derived relational responding in accordance with frames that had been found to be absent in the behavioural repertoire of participants (Barnes-Holmes, Barnes-Holmes, Smeets, Strand & Friman, 2004). Initially a population of children were presented with a problem solving task using coins to test and train responding in accordance with more than and less-than relations. The children were presented with wooden coins of exactly the same size and the experimenter described how the coins compared to each other in terms of value. The experimenter then asked the children to pick the coin that would buy as many sweets as possible. Sometimes the trials involved the presentation of two coins with the child being told that one coin (coin A) would buy more than another coin (coin B). On other trials involving three coins the child was told that one coin would buy more sweets than another coin but that this coin would also buy less sweets than another coin (i.e. A<B<C). Numerous sets of coins were employed to create multiple exemplars for training and testing these types of task.

The results of this study showed that all participants required between 30 and 40 training and testing exposures before demonstrating responding in accordance with the arbitrary relations of more-than and less-than. This suggests that a significantly higher number of exposures were required to train responding in accordance with frames that were not previously present in a child’s behavioural repertoire relative to frames that were already present. The results provided evidence that derived relational responding might be established ab initio through a history of multiple exemplar training. Indeed, a further experiment used a similar procedure to train children to respond according to the fame of opposite (Barnes-Holmes, Barnes-Holmes, & Smeets, 2004). Exemplar training has also been shown to be effective in facilitating the emergence of other novel repertoires such as flexible symmetry and asymmetry responding (O'Toole, Barnes-Holmes, Murphy, O'Connor, & Barnes-Holmes, 2009); and derived transfer of mand functions (Murphy, Barnes-Holmes & Barnes-Holmes, 2005).

Disrupting Derived Relational Responding

A growing body of RFT research has begun to demonstrate that derived relational responding may be facilitated and perhaps even established through an appropriate history of exemplar training (Barnes-Holmes, Barnes-Holmes, Roche & Smeets, 2001a; Barnes-Holmes, Barnes-Holmes, Roche & Smeets, 2001b; Barnes-Holmes, Barnes-Holmes, Smeets, Strand & Friman, 2004, Barnes-Holmes, Barnes-Holmes & Smeets,2004, Gomez, Lopez, Marin, Barnes-Holmes, & Barnes-Holmes, 2007; Berens & Hayes, 2007). However, other RFT research has also examined variables that apparently inhibit or prevent the emergence of laboratory induced derived relations (e.g., Stewart, Barnes-Holmes, Roche, & Smeets, 2002; Barnes, Lawler, Smeets, & Roche, 1995; Watt, Keenan, Barnes, & Cairns, 1991). The earliest studies in this area demonstrated this "inhibition" effect by deliberately employing stimuli that likely participated in pre-experimentally established relational frames, but were in conflict with the to-be-induced frames within the experimental context. The first of these studies was conducted in Northern Ireland with English and Irish undergraduates (Watt et.al., 1991). Specifically, participants were exposed to a MTS training procedure that would predict the emergence of equivalence relations between Catholic names and Protestant symbols. The results of this study showed, however, that a large proportion of Irish participants chose the untrained Protestant names in the presence of the Protestant symbols. In effect, the pre-experimentally established relation between the Protestant names and symbols interfered with the formation of equivalence relations between the Protestant symbols and Catholic names. In contrast, the English participants did not show this interference effect, as would be predicted given that they lacked the pre-experimental exposure to the social contingencies operating in Northern Ireland.

In a broadly similar study, Barnes, Lawler, Smeets, and Roche (1995) examined academic self-concept in normally developing and mildly learning disabled children. The participants were exposed to two stimulus equivalence procedures; one involving neutral shapes, and one that used socially loaded words and the participants' names as stimuli. The neutral equivalence procedure served as a control condition with only those participants who demonstrated equivalence responding being tested in the second condition. The socially loaded equivalence procedure used B stimuli that incorporated words such as "slow" and "able" that were judged to be pertinent to academic self-concept. Personal names of the participants were included as C stimuli. The MTS training was designed such that the participants name was induced to form an equivalence relation to the word "able" and a fictional name was induced to form an equivalence relation with the word "slow." The study found that participants with a learning disability produced a significantly lower number of equivalence responses relative to the children in the normative group (i.e., the learning disabled participants matched their own name to "slow" significantly more often than the normative group). Insofar as individuals with learning difficulties typically display less positive self-concept concerning academic achievements than their normative peers (Battle & Blowers, 1982; Jones, 1992), the results of the Barnes et. al. study suggest that pre-experimentally established verbal relations between a participant's own name and negative descriptors may have interfered with the formation of the laboratory induced equivalence relations.

The studies reported by Watt et al. (1991) and Barnes et al. (1995) involved examining the effects of conflicting laboratory-induced equivalence relations with equivalence relations that were likely established in the pre-experimental environment. In these studies the two sets of conflicting relations were completely arbitrary in that the stimuli were composed of words from natural language. In a more recent study, however, the effect of competing relations on equivalence responding was examined, but in this case the competing relations were non-arbitrary in nature (Stewart, Barnes-Holmes, Roche & Smeets, 2002). Specifically, during equivalence testing the predicted equivalence relations involved stimuli that differed in colour, whereas the non-equivalent sample-comparison relations involved stimuli that matched in terms of colour.

In this study, the critical condition involved training participants using stimuli that appeared in black and then presenting the same stimuli during the equivalence test in various colours. Performance during this Colour-Test condition was significantly poorer than in two control conditions. The first of these involved a standard training and testing procedure in which the stimuli were all presented in black, and another condition in which subjects were *trained and tested* using colour stimuli (i.e., in this latter condition subjects were trained to "ignore" colour before the equivalence test). In effect, only the Colour-Test condition involved an equivalence test in which there was competition between arbitrary (equivalence) and non-arbitrary (colour matching) stimulus control, and this competition appeared to produce lower levels of equivalence responding than the two control conditions.

Interestingly, the study of the effects of competing stimulus relations on derived relational responding may provide a possible methodology for the study of behavioural phenomena that seem relevant to what cognitive researchers have described as executive function. In broad terms, EF apparently involves high levels of attention and cognitive effort to overcome competing alternative responses. The procedures and data reported by Stewart et al. (2002) might also be viewed in a similar manner. When a participant was presented with a sample stimulus during a test trial in the Colour-Test condition, two conflicting responses were available; one that required the derivation of an arbitrary equivalence relation and one that required a "simple" non-arbitrary colour matching response. Insofar as the latter response requires less behavioural "effort" relatively high levels of colour-matching over derived equivalence responding could be seen as indicating poor EF.

The research reported by Stewart et al. (2002) is the only published study to report the apparently disruptive effects of non-arbitrary stimulus relations on derived equivalence relations, and thus there is a clear need to investigate this effect in considerable detail. Indeed, a systematic analysis of the effect is required before we can even begin to develop it as a behaviour-analytic methodology for assessing EF. The research reported in the current thesis constitutes a first attempt to analyse the effects of conflicting non-arbitrary stimulus relations on derived relational responding in normal adults, and both normally developing and autistic populations.

Chapter 2

CHAPTER 2

Competing Arbitrary and Non-arbitrary Stimulus Relations: The Effect of Exemplar Training in Adult Participants

A growing body of RFT research has examined the variables that apparently inhibit or prevent the emergence of laboratory induced derived relations (e.g., Stewart, Barnes-Holmes, Roche, & Smeets, 2002; Barnes-Holmes, Barnes-Holmes, Roche, & Smeets, 2001; Watt, Keenan, Barnes, & Cairns, 1991; Barnes, Lawler, Smeets, & Roche, 1995). RFT predicts that it is possible to interfere with the formation of derived arbitrary relational responding through introducing a possible competing non-arbitrary relational response in a test setting. However, there is only one study in the literature that examines the relationship between non-arbitrary and arbitrary relational responding in a systematic manner (Stewart, Barnes-Holmes, Roche, & Smeets, 2002).

In the Stewart et al. study participants were taught three A-B and three B-C matching to sample (MTS) tasks. For the three A-B tasks each participant was presented with A1, A2 or A3 as the sample stimulus and then had to choose among comparisons B1, B2, or B3 (see Fig. 5 for representation). The correct response was B1 given A1, B2 given A2 and B3 given A3. For the B-C relations the participants received training to match B1-C1, B2-C2, and B3-C3. After this training procedure was completed participants were tested for C-A equivalence responding.

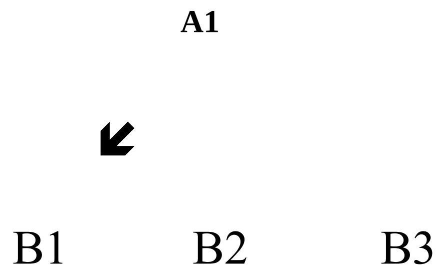

Figure 5. A1 - B1 match to sample training trial:

The participants were also divided into three separate groups; *No-Colour, All-Colour, and Colour-Test*. Each of these groups was exposed to different training and testing procedures. The *All-Colour* Group was referred to as such because *all* of the stimuli to which the participants were exposed throughout the study were coloured. In this case, the correct comparison stimulus was the same colour as the sample on some trials and a different colour on other trials. In effect, this procedure taught the participant to “ignore” the property of colour as the basis for correct responding (see Fig. 6 for representation).

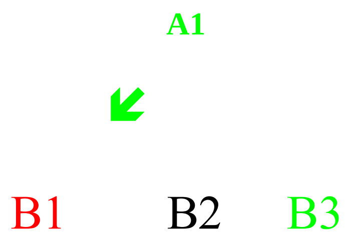

Figure 6. All-Colour MTS task with competing non-arbitrary relation of colour.

The *No-Colour* group were exposed to a training procedure identical to the *All-Colour* group with except that black stimuli were used during both training and testing. There was, therefore, no conflicting non-arbitrary relation between the stimuli that could hinder the formation of arbitrary relations.

The participant group that are specifically of interest here are the *Colour-Test* group. This group were referred to as such because all of the stimuli presented in the basic conditional discrimination training were black, whereas the stimuli presented during the equivalence test were coloured. For these participants, the novel presence of colour as a feature of the test stimuli might be expected to conflict with the arbitrary relational response established with black stimuli during training. In other words, the training did not provide a history in which participants indirectly learned to ignore colour as a salient feature. The design of this testing procedure was such that for two thirds of trials the "correct" comparison stimulus was a different colour to the sample stimulus while for the remaining one third the equivalent (correct) stimulus was the same colour as the sample. The objective of this test condition was to determine if participants would respond on the basis of an arbitrary equivalence relation (derived from their *experimental training history*) or on the basis of a non-arbitrary sameness relation of colour when both relations were present.

The results of this study indicated, as predicted, that the *All-Colour* group produced greater accuracy on the equivalence test than the *Colour-Test* group. Furthermore, the errors produced by the *Colour-Test* group consisted of responses that tended to involve matching the stimuli simply on the basis of colour.

Current experiment

The overall aims of the present experiment were two-fold. One aim was to extend the work of Stewart et al. (2002) by investigating further the effect of different types of experimental training history, with regard to colour, on participants' performances in equivalence tests. Toward this objective, half of the participants were assigned to an A*ll-Colour* group and, as in the Stewart et al. study, were presented with an MTS training and testing procedure using coloured stimuli throughout. The other half of the participants in this experiment were assigned to a *Colour-Test* group, similar to that employed by Stewart et al. (i.e., No colour training followed by colour testing).

The second key aim of the current experiment was to determine if equivalence responding with different experimental histories with regard to colour (i.e., *All-Colour* compared to *Colour-Test*) could be improved using further training with multiple exemplars. As described in the first chapter, recent research on the efficacy of multiple exemplar training with derived relations suggests that this type of training paradigm might prove useful in training participants *not* to be influenced by conflicting non-arbitrary relations (Barnes-Holmes, Barnes-Holmes, Roche, & Smeets, 2001). Consider, for example, a participant from the *Colour-Test* group who persistently fails the equivalence test by responding on the basis of colour. Could subsequent equivalence test performances involving novel coloured stimuli be improved by explicitly training the arbitrary C-A relations across three separate sets of stimuli? In this way, despite repeated exposures to training involving only black stimuli, the participant might learn across the three exemplars to ignore colour as a salient feature of the test stimuli. Half of the participants from both the *All-Colour* and *Colour-Test* groups received this type of training. These groups are referred to as Exemplar-Training-All-Colour (*Exemplar All Colour*) and Exemplar-Training-Colour-Test (*Exemplar Colour Test*), respectively.

In order to determine the efficacy of the exemplar training, the remaining participants from the All-Colour and Colour-Test groups were simply exposed to repeated equivalence test phases – would repeated exposure alone be sufficient to improve equivalence performances? These groups are referred to as Repeated-Test-All-Colour (*Repeat All Colour*) and Repeated-Test-Colour-Test (*Repeat Colour Test*), respectively. The participants were, therefore, divided into 4 groups of equal number. The basic experimental design involving the four groups is presented in Table 1.

Table 1. The Basic Experimental Design Employed in the Experiment.

Participant Groups	**Stimulus Sets**		
	Set 1	*Set 2*	*Set 3*
Repeat-All Colour	CA Test CA Test	CA Test CA Test	CA Test CA Test
Exemplar- All Colour	CA Test CA Train	CA Test CA Train	CA Test CA Train
Repeat- Colour Test	CA Test CA Test	CA Test CA Test	CA Test CA Test
Exemplar-Colour Test	CA Test CA Train	CA Test CA Train	CA Test CA Train

Method

Participants

Thirty-two undergraduate students from the National University of Ireland, Maynooth participated in the current experiment, seventeen were female and fifteen were male. Participants ranged in age from 18-25 years, with a mean age of 20.3 years. All of the participants were recruited through personal contacts of the experimenter and none had any prior knowledge of stimulus equivalence or experimental psychology. Participants were randomly assigned to one of four experimental groups, with eight participants assigned to each group. None of the participants received any remuneration for taking part in the experiment.

Setting, Apparatus, and Materials

All participants completed the experiment in a small quiet experimental room located in the Department of Psychology. Each participant was seated at a desk that contained an iMac computer. The iMac had a Power PC G3 400MHz Processor (OS 9) with a 15-inch colour monitor. Participants interacted with the computer by using three designated keys (Z, V, and M) located on the left, middle, and right of the computer keyboard, respectively. The three response keys were each distinguished with a small yellow sticker, on which the appropriate letter was clearly marked. Computer programs controlled all of the stimulus presentations and simultaneously recorded all of the participants' responses. The programs were written in BBC BASIC and were adapted from those employed by Stewart, et al. (2002). The same basic computer program was employed throughout the experiment with only minor modifications made for each of the four participant groups.

The experimental stimuli were twenty-seven three-letter nonsense syllables that were randomly divided into three sets of nine stimuli, hereafter referred to as Sets 1-3. The nine stimuli contained within each set were then subdivided into three three-member stimulus classes (i.e., there were three three-member classes within each of the three sets). For ease of communication within the current report, each of the twenty-seven nonsense syllables was designated with an alphanumeric label pertaining to a particular class. The organization of the stimuli and their alphanumeric labels are presented in Table 2. Participants were not exposed to the alphanumeric labels at any time. On some occasions, the nonsense syllables were presented on screen in one of three colours (red, green, or blue), whereas on other occasions they were printed in black only. The presence or absence of stimulus colour presented to the participants depended on the experimental group to which they had been assigned (see Table. 2). In addition to the nonsense syllables, participants were provided with a set of instructions typed on an A4 sheet of paper at the beginning of the experiment.

Table 2. The Experimental Stimuli and Designated Alphanumeric Labels Employed in the Experiment.

Stimulus Sets and Classes		
Set 1	*Set 2*	*Set 3*
ZID (A1)	BEM (A4)	WIK (A7)
MAU (B1)	PID (B4)	MUJ (B7)
JOM (C1)	NOS (C4)	JUR (C7)
VEK (A2)	DOK (A5)	LOP (A8)
WUG (B2)	JAD (B5)	ZUN (B8)
BIF (C2)	LUD (C5)	NID (C8)
YIM (A3)	SEP (A6)	SOM (A9)
DAX (B3)	COL (B6)	CAJ (B9)
PUK (C3)	ZUR (C6)	DUP (C9)

General Procedure

Participants completed the experiment individually, and required only one experimental session that lasted approximately one hour. Once seated at the computer, the participant was verbally instructed as follows:

> Please read the typed instructions on the desk. At various points throughout the experimental session a message will appear on the computer screen. This will signal the end of that part of the experiment. I will be seated outside, please come and inform me when this happens.

The experimenter remained in the room while each participant read the typed instruction sheet containing the following information:

> This is an experiment designed to investigate adult learning and reasoning abilities. There is no "trick" or hidden agenda behind this experiment, it is concerned only with your ability to learn and reason. During the experiment you will be presented with nonsense syllables (VEK, COL, MUJ, etc.). Your task is to learn which one of the three nonsense syllables that appears at the bottom of the screen "goes with" the one at the top.
>
> At first, there is no way you can know which is the correct choice, but each time you choose, the computer will tell you whether you chose the correct or wrong nonsense syllable. With enough experience, you will learn which nonsense syllables go together.

> After you have mastered these performances, the computer will then present you with a “test” without feedback (i.e., you will not be told whether your choices were right or wrong). During the test, there is always a correct choice based on what you have learned, so be careful to pay close attention during the first part of the experiment.
>
> Again, it must be stressed that there is no hidden “trick” involved here. Your job is simply to learn, via trial-and-error, which nonsense syllables go together, and then to pass a test based on what the computer has previously taught you.
>
> Please note. You choose the nonsense syllable that appears on the left of the screen by pressing the marked key on the left. You choose the nonsense syllable that appears in the middle by pressing the marked key in the middle. You choose the nonsense syllable that appears on the right by pressing the marked key on the right.

All of the experimental trials in the current experiment were presented in a matching-to-sample format. On each trial, a sample stimulus appeared in the top centre portion of the screen, and three comparison stimuli appeared along the bottom, one on the left, one in the middle, and one on the right. Participants were simply required to choose the comparison that ‘went with’ the sample by pressing the appropriate key on the keyboard. Participants selected the left, middle, or right comparison by pressing the Z, V, or M keys that were located on the left, middle and right of the keyboard, respectively.

The matching-to-sample format was employed in the current experiment to establish a total of nine three-member equivalence classes, divided across the three stimulus sets – Sets 1-3. These classes were as follows: Set 1 consisted of the classes A1-B1-C1, A2-B2-C2 and A3-B3-C3; Set 2 consisted of the classes A4-B4-C4, A5-B5-C5 and A6-B6-C6; Set 3 consisted of the classes A7-B7-C7, A8-B8-C8 and A9-B9-C9 (see Table 2). Training within each set required that the participants learn the A-B and B-C conditional discriminations among the three classes. Testing with each set involved presenting each of the three C stimuli as samples with the three A stimuli as comparisons. The training and testing for each set was achieved across three experimental phases. After completing the equivalence test in Phase 3, for each set, participants in Phase 4 received either a second test exposure (i.e., participants in the Test groups) or a second exposure that involved corrective feedback (i.e., participants in the Train groups). Overall, therefore, participants were exposed to four experimental phases for each stimulus set. After exposure to Set 1, participants were subsequently exposed to the four phases in Set 2 in the same way and finally to Set 3. A schematic representation of the experimental phases employed for each stimulus set is presented in Figure 7.

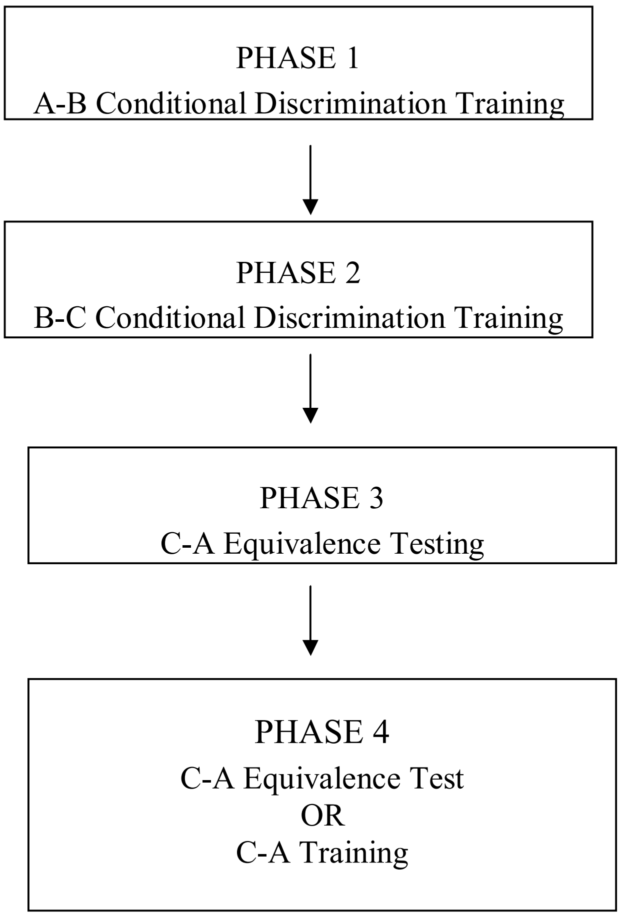

Figure 7. A schematic representation of the experimental phases conducted within each stimulus set.

Programmed Consequences

A correct response during all training trials was followed by the word "CORRECT", printed in black Arial 72, which appeared in the centre of the screen immediately after the participant's response. This feedback was accompanied by a high-pitched tone. An incorrect response was similarly followed by the word "WRONG", but no explicit tone was audible. Programmed consequences were employed with all training trials, but no programmed consequences followed any test trial.

Procedure

All participants were exposed to the same experimental sequence that consisted of three exposures (one for each stimulus set) to four phases of training and testing. Participants completed Phases 1-4 in that order for each set, before proceeding to the next set.

Phase 1: A-B Training. All participants were first exposed to the AB relations in Set 1. This phase consisted of 18 training trials in which the A1-B1, A2-B2, and A3-B3 relations were explicitly trained. Specifically, participants were presented with A1, A2, or A3 as the sample and B1, B2, and B3 as the comparisons. A correct response involved selecting B1 (rather than B2 or B3) in the presence of A1, B2 in the presence of A2, and B3 in the presence of A3.

The block of 18 AB training trials was presented in a pre-determined quasi-randomly ordered sequence that was identical for all participants. What differentiated the participant groups at this point was the presentation of the A and B stimuli in either black lettering only or in colour. For participants in the two *Colour-Test* groups, all of the A and B stimuli presented during Phase 1 appeared in black only, whereas the stimuli appeared in colour for participants in the two *All-Colour* groups. As well as counterbalancing the locations of the comparison stimuli, the use of colour required two additional features of counterbalancing to ensure: (1) that the same colour did not consistently appear in a particular location, and (2) that the correct comparison was the same colour as the sample on only one third of the trials. After completing the 18 A-B training trials in Phase 1, participants proceeded immediately to Phase 2, irrespective of their performances on the A-B relations.

Phase 2: B-C Training. Training the B-C relations was identical to Phase 1, except that participants were presented with B1, B2, or B3 as the sample and the three C stimuli as comparisons. In this way, the relations B1-C1, B2-C2, and B3-C3 were established for Set 1. Once again, this training consisted of six exposures to each of the three B-C trial-types, and were presented in a pre-determined quasi-randomly ordered sequence that was identical for all participants (the same colour and position counterbalancing was employed as in Phase 1). In order to proceed to Phase 3, participants were required to reach a mastery criterion of 33 correct responses out of the combined 36 A-B and B-C training trials. Participants who did not reach this criterion after the B-C trials were immediately re-exposed to the A-B training followed by the B-C training, and this retraining continued until the mastery criterion was reached. This procedure was employed to ensure that participants had successfully demonstrated the conditional discriminations before proceeding to the equivalence test phase.

Phase 3: C-A Testing. The C-A equivalence testing in Phase 3 was identical in format to the previous phases, except that no corrective feedback was provided. The test consisted of 36 trials with twelve exposures to each of three C-A trial-types, in which C1, C2, or C3 was the sample and the three A stimuli were the comparisons. Once again, the CA test trials were presented in a pre-determined quasi-randomly ordered sequence that was identical for all participants. Correct responding in accordance with the designated equivalence relations in Set 1 was defined as selecting A1 in the presence of C1, A2 in the presence of C2, and A3 in the presence of C3 (i.e., the relations C1-A1, C2-A2, and C3-A3 were designated as correct based on the previous training). It is important to emphasize that all participants were presented with the equivalence test trials in colour. No test trials were consequated by feedback of any kind and thus trials were presented one after another with an inter-trial interval of 2 s. All participants proceeded to Phase 4 irrespective of their performances on the equivalence test.

Phase 4: C-A Testing or C-A Training. The specific nature of Phase 4 to which participants were exposed depended on the group to which they had been assigned. For participants in the *Test* groups (i.e. *Repeat All Colour* and *Repeat Colour Test* groups), Phase 4 was identical to Phase 3 and simply involved a second identical exposure to the equivalence test, using the same stimulus set employed in the previous phase. For participants in the *Train* groups (i.e., *Exemplar All Colour* and *Exemplar Colour Test* groups), Phase 4 was also identical to Phase 3, except that corrective feedback now consequated each trial. In this way, Phase 4 constituted a type of exemplar training (using the stimulus set that had previously been employed in testing). Irrespective of condition and performance, all participants were exposed to the same block of 36 trials in Phase 4 and thereafter continued immediately with the rest of the experiment.

After completing Phase 4 with Set 1, all participants were given a short break of two minutes, after which they were immediately exposed to the same training and test sequence with Set 2. All aspects of training and testing in Phases 1-4 with Set 2 were identical to Set 1, except that three novel three-member classes (A4-B4-C4, A5-

B5-C5, and A6-B6-C6) were trained and tested. Once again, the use of black or coloured stimuli during the conditional discrimination training in Phases 1 and 2 differentiated the *Colour-Test* and *All-Colour* groups and the use of corrective feedback in Phase 4 differentiated the Train and Test groups. Once participants had completed the C-A trials in Phase 4 with Set 2, they were once again given a two-minute break and thereafter proceeded immediately to training and testing with Set 3.

All aspects of training and testing in Phases 1-4 with Set 3 were identical to the previous sets, except that three novel three-member classes (A7-B7-C7, A8-B8-C8, and A9-B9-C9) were trained and tested. All participants followed this basic format of Phases 1-4 across Sets 1-3 in that order. After completing the last block of C-A trials in Set 3, all participants were presented with the following instruction on the computer screen: "That is the end of the experiment. Please contact the Experimenter." For all participants, this marked the end of the experiment.

Results

The current experiment had two key aims. First, participants were divided into *All-Colour* and *Colour-Test* groups to investigate the effect of different experimental training histories with regard to colour on equivalence test performances when the arbitrary and non-arbitrary relations were conflicting. It was predicted that participants in the latter groups (*Repeat Colour Test* & *Exemplar Colour Test* groups) would be more sensitive to the conflict between the arbitrary and the non-arbitrary relations during the equivalence test and would thus likely produce weaker equivalence outcomes. The second aim of the experiment was to determine if equivalence could be increased with explicit C-A training across multiple stimulus sets or if repeated exposure alone to multiple sets would be sufficient to facilitate improvements in equivalence. Half of the participants (i.e., *Exemplar Colour Test* and

Exemplar All Colour groups) received explicit C-A training in Phase 4, whereas the other half (i.e., *Repeat Colour Test* and *Repeat All Colour* groups) received repeated exposures to C-A testing within each set. The data generated by participants across all four conditions were analyzed using accuracy on C-A trials as the dependent variable.

All participants in the current experiment were exposed to a total of six blocks of 36 C-A trials presented across three stimulus sets (two in each set), hereafter referred to as Exposures 1 and 2 in Set 1, Set 2, and Set 3. The mean accuracy scores (with standard error bars) of participants in each of the four groups during Exposures 1 and 2 for each of the three stimulus sets are presented in Figure 7.

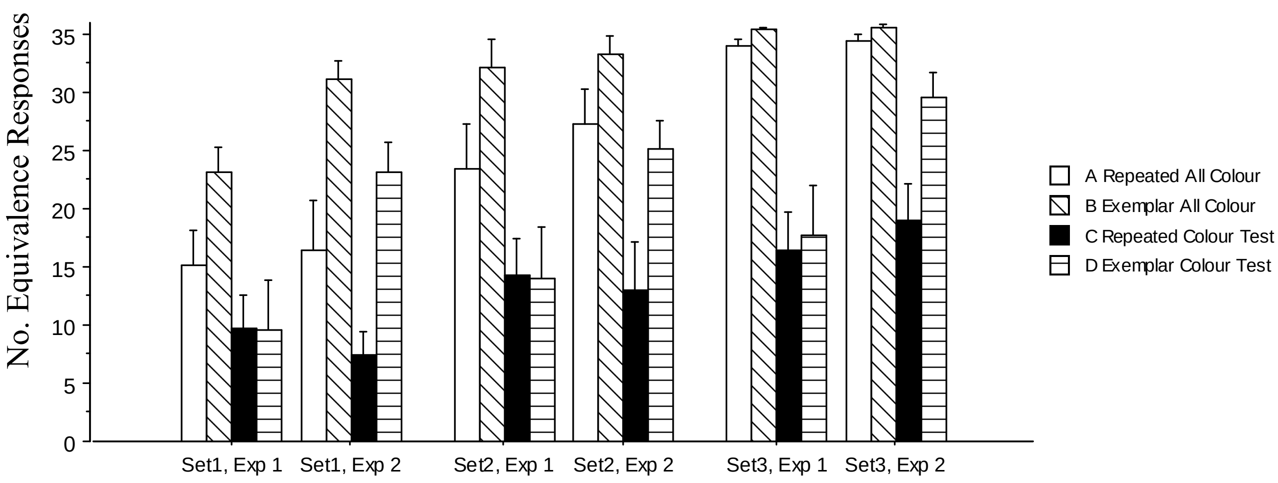

Figure. 7. Equivalence-consistent responding for all groups across three stimulus sets.

Figure. 7 indicates notable differences in the equivalence performances of participants in the four experimental groups. The sixteen participants in the two *All-Colour* groups produced the highest levels of accuracy on equivalence. Participants in the *Exemplar All Colour* group produced the most accurate equivalence scores across all three sets with accuracy increasing across sets, particularly after the C-A training in Exposure 1 of Set 1. Mean accuracy scores for this group ranged from 23.125

(SD=5.9) in Exposure 1 of Set 1 to 35.6 (SD=0.744) in Exposure 2 of Set 3. Participants in the *Repeat All Colour* group also produced relatively high levels of accuracy on equivalence, again with an improving trend across sets (mean accuracy scores ranged from 15.125 (SD=8.5) in Exposure 1 of Set 1 to 34.38 (SD=1.6) in Exposure 2 of Set 3.

Participants in the *Exemplar Colour Test* group produced lower levels of accuracy on equivalence overall. On the first test exposure to Set 1, these participants produced only low levels of accuracy but this performance improved greatly in the C-A training provided in the second exposure. These improvements, however, did not appear to be retained in the equivalence test in Set 2, although performances improved again with explicit C-A training. A similar pattern of responding was recorded with these participants on Set 3, with the final performance in Exposure 2 of Set 3 demonstrating a relatively high level of accuracy overall. The mean accuracy scores for this group ranged from 9.625 (SD=11.9) in Exposure 1 of Set 1 to 29.6 (SD=6.0) in Exposure 2 of Set 3, indicating a sizeable improvement. In contrast, participants in the *Repeat CT* group produced the lowest equivalence scores overall and their performances remained relatively low even for Exposure 2 of Set 3. The mean accuracy scores for this group ranged from 9.75 (SD=5.5) in Exposure 1 of Set 1 to 19.0 (SD=9.1) in Exposure 2 of Set 3.

Statistical analyses were conducted on the equivalence accuracy data to determine if any of the differences between the groups across the two exposures within the sets were significant. A 4×3×2 Mixed Repeated Measures (RM) Analysis of Variance (ANOVA) was conducted with participant group as the between-subject variable, and stimulus set and exposure as the within-subject variables. The results of this analysis indicated three highly significant main effects for group [F (3,28) =

12.332, $p < .0001$]; stimulus set [$F(2,28) = 43.423$, $p < .0001$]; and exposure [$F(1,28) = 22.408$, $p < .0001$]. Two significant interaction effects were also obtained between group and stimulus set [$F(6,56) = 2.494$, $p = .039$], and between group and exposure [$F(3,28) = 9.619$, $p = .0002$]. Finally, a marginally significant three-way interaction was also produced [$F(6,56) = 2.112$, $p = .0661$]. These findings support the interpretation above and indicate that there were significant differences in the equivalence performances among the various participant groups, across the three stimulus sets, and between the first and second C-A exposures within each set. The interaction effects also indicate that the changes in equivalence outcomes of the participant groups on each exposure were determined to some extent by participation in a particular group.

The results thus far may be summarized as follows. The accuracy scores indicated significant differences among the four participant groups. The two All-Colour groups produced better equivalence performances than the Colour-Test groups. Participants in the *Exemplar All Colour* group produced the best equivalence performances and participants in the *Repeat Colour Test* group produced the weakest. There were also considerable differences between Exposures 1 and 2, suggesting an effect for the training or testing that occurred on the second block of C-A trials in each set. Equivalence responding for all groups increased across the three sets.

Error Analyses

Colour-matching errors. Inaccurate equivalence responses may have resulted from one of two patterns of responding because each C-A trial contained three comparisons. One comparison was correct in terms of the conditional discrimination training history but was the same colour as the sample on only one third of the trials. Another comparison was the same colour as the sample but was incorrect in terms of the training history on two thirds of the trials. A third comparison was also incorrect but was not the same colour as the sample on all trials (referred to hereafter as the neutral comparison). Figure 8 presents the errors made by participants in the four groups in which they selected the comparison that was the same colour as the sample, and as such responded in accordance with the non-arbitrary sameness relation of colour. The data show that the errors of selecting the colour-matched comparison made by the *Repeat All Colour* group clearly decreased across all consecutive exposures. This suggests that repeated test exposures taught participants to ignore colour as a salient feature of the stimuli. The *Exemplar All Colour* group produced fewer colour errors than the *Repeat All Colour* group overall, as would be expected because of the explicit C-A training, and these errors decreased consistently across the sets.

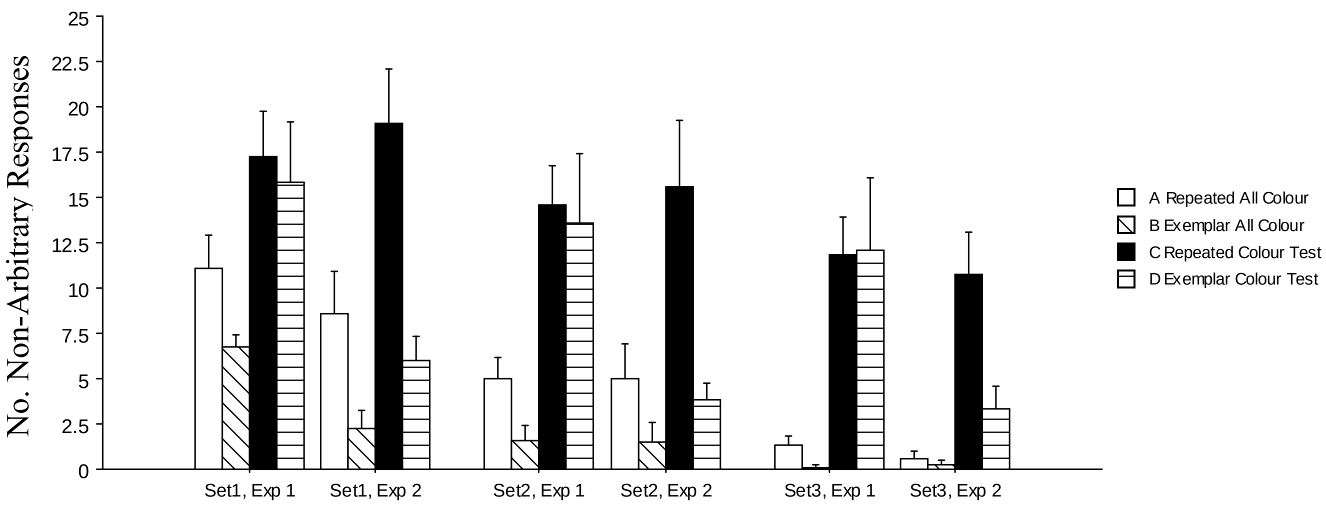

Figure. 8. Number of responses according to non-arbitrary relation by all groups across three stimulus sets

The data for both of the Colour-Test groups showed more colour errors than the All-Colour groups. For the *Repeat Colour Test* group, the pattern of colour errors remained high but somewhat variable across the sets, although a general decreasing trend was observed (see Figure 8). Participants in the *Exemplar Colour Test* group produced a distinctive pattern of colour responses in which the tests contained a high number of colour responses whereas the training did not. This would suggest that the explicit C-A training decreased the colour errors but this effect was not maintained during the subsequent test and this pattern appears to have been repeated across the three sets.

The error data were subjected to a 4×3×2 Mixed RM ANOVA with participant groups as the between-subject variable, and stimulus set and exposure as the within-subject variables. The results of this analysis indicated three significant main effects for group [$F\ (3,28) = 12.16$, $p < .0001$], stimulus set [$F\ (2,28) = 43.\ 28.18$, $p < .0001$], and exposure [$F(1,28) = 10.85$, $p = .003$], with a significant interaction effect between exposure and group [$F(3,28) = 6.65$, $p = .002$]. Once again, the inferential statistics support the data presented in Figure 4. Specifically, number of errors was determined by both group and exposure.

Neutral errors. Figure 9 presents the participants' errors in which they selected the neutral comparison stimulus. The data show that the neutral errors made by the *Repeat All Colour* group were variable but generally decreasing across sets. The *Exemplar All Colour* group produced fewer neutral errors, a pattern which again decreased consistently across the sets. Both of the Colour-Test groups produced more neutral errors than the All-Colour groups and this pattern of neutral errors remained high but variable across the sets (the *Exemplar Colour Test* group showed a particular decrease between the two exposures in Set 3).

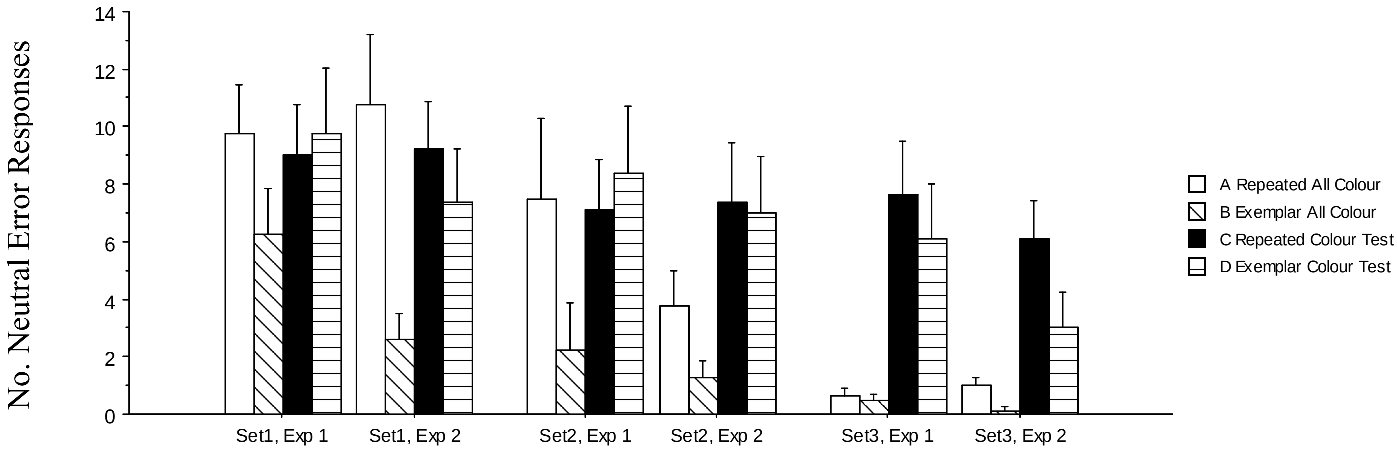

Figure. 9. Number of neutral errors for all groups across three stimulus sets.

The neutral error data were subjected to a 4×3×2 Mixed RM ANOVA with participant groups as the between-subject variable, and stimulus set and exposure as the within-subject variables. The results of this analysis indicated three significant main effects ($ps < .05$), with no interactions. Similar to the colour-matching errors, the inferential statistics indicate that the number of neutral errors was determined by both group and exposure.

Summary

The results from the current experiment may be summarized as follows. The accuracy scores for correct equivalence responses indicated significant differences between the four participant groups. The two All-Colour groups produced better equivalence performances than the Colour-Test groups. Participants in the *Exemplar All Colour* group produced the best equivalence performances and participants in the *Repeat Colour Test*

Exposures 1 and 2, suggesting an effect for the training or testing that occurred on the second block of C-A trials in each set. Equivalence responding for all groups increased across the three sets. Analyses of the error data indicated that the *Exemplar All Colour* group produced fewer colour errors than the *Repeat All Colour* group overall and these errors decreased consistently across the sets. Both of the Colour-Test groups produced many more colour and neutral errors than the All-Colour groups. For the *Repeat Colour Test* group, the pattern of neutral errors remained high but variable across the sets whereas for the *Exemplar Colour Test* group these errors decreased gradually across the sets.

Discussion

The results of the current experiment were largely in keeping with the experimental predictions. The participants in the All-Colour groups (who were exposed to coloured stimuli during training and testing) produced superior equivalence performances compared to those participants exposed only to colour stimuli during the C-A trials (*Repeat Colour Test* group). This finding suggests that a history of training with colour helped the *All-Colour* participants to learn to ignore colour as a salient stimulus dimension. The explicit C-A training did improve the equivalence performances of participants, although some improvements were made simply by repeated exposure to the C-A test. The errors made by the *Colour-Test* groups were predominantly responses in accordance with non-arbitrary colour-matching and suggested that the weaker equivalence performances did indeed result from a conflict between the arbitrary and non-arbitrary stimulus dimensions. This finding is entirely consistent with predictions made by RFT and lends firm support to the previous study by Stewart et al. (2002). As an extension to the earlier study, the current work also produces new empirical evidence supporting the efficacy of exemplar training in the establishment of derived stimulus relations.

An interesting conclusion that emerges from the current experiment is that the exposure to the *All Colour* conditions appeared to improve C-A equivalence responding to a larger degree than exemplar training *per se*. By Set 3, Exposure 1, both of the *All Colour* groups were producing high levels of equivalence responding, but the two *Colour Test* groups were not. In fact, the latter two groups produced very similar performances, thus indicating that the exemplar training had little impact relative to simple repeat exposures. This outcome seems to be at odds with the RFT emphasis on the role of exemplar training in producing derived relational responding (Barnes-Holmes & Barnes-Holmes, 2000). On balance, of course, the experiment involved exposure to only three stimulus sets and thus perhaps additional exposures to more exemplars would have produced the predicted effect (see Murphy, Barnes-Holmes, Barnes-Holmes, 2005).

Data for the *Exemplar Colour Test* group showed a significant increase in levels of equivalence-consistent responding in exposure 2 when compared to exposure 1 for each stimulus set. A similar trend was not seen in the data of the *Repeat Colour Test* group, which showed little difference in arbitrary relational responding in exposure 2 relative to exposure 1 across all stimulus sets. This result suggests that exemplar training received by the *Exemplar Colour Test* was a successful intervention for reducing the interference effect of competing non-arbitrary stimulus relations on the formation of arbitrary relational responses for that group. However, the increases in arbitrary relational responding for the *Exemplar Colour Test* group were not maintained across stimulus sets with equivalence responding in exposure one of the second stimulus set falling to levels similar to those of the *Repeat Colour Test* group. Although levels of equivalence-consistent responding increased during exposure 2 of the second set, they decreased again to levels similar to the repeated *Repeat Colour Test* group for exposure 1 of the third stimulus set. These results suggest that the increases in equivalence-consistent responding brought about through the exemplar training procedure did not generalise from one stimulus set to the next.

The data for the *Exemplar All Colour* group showed increases in equivalence-consistent responding across exposures in all stimulus sets and produced near error-less equivalence responding by exposure 1 of the stimulus set 3. There was no decrease in equivalence responding observed across sets suggesting that the participants learned to “ignore” the competing non-arbitrary colour relation through training with coloured stimuli and generalised this learning across sets. The participants in the *Exemplar Colour Test* group received exemplar training with stimuli coloured black and demonstrated significantly lower levels of colour matching responding in the second exposure for all stimulus sets (See Fig. 7). Exemplar training taught participants in this group to ignore the non-arbitrary relation of colour in exposure 2 for that stimulus set, but arbitrary relational responding decreased when they were exposed to a novel stimulus set. Future research could investigate procedures for providing participants in the *Exemplar Colour Test* group with additional exemplar training exposures prior to exposure 1 of each novel stimulus set. This might increase arbitrary relational responding and teach participants to successfully ignore the competing non-arbitrary relation of colour present during testing.

Alternative training procedures could also investigate exposing participants to training and testing conditions with black stimuli until they reach a criterion level of arbitrary relational responding during testing prior to exposing them to a *Colour-Test* condition. This would ensure that the participant had successfully acquired the arbitrary relational responses prior to the introduction of the competing non-arbitrary colour relation.

A modest increase in arbitrary relational responding across the three stimulus sets was observed for the *Exemplar Colour Test* group, however, a similar trend can be seen in the data for the *Repeat Colour Test* group. It could be argued that the increases in equivalence–consistent responding across sets observed for both groups could be attributed to a treatment effect whereby the participant's performance increased due to repeated exposures to the training and test procedures rather than through exposure to additional exemplar training procedures.

Examination of the error data for responses according to colour shows a decrease in colour responding across sets for the two *All Colour* groups (*Repeat All Colour* and *Exemplar All Colour*). This suggests that the participants in these groups learned to ignore the competing non-arbitrary relation of colour and this was maintained across sets. The number of colour errors was lower in the *Exemplar All Colour* group compared to the *Repeat All Colour* group suggesting that the exemplar training procedures the former group were exposed to increased equivalence responding relative to the performance observed for the *Repeat All Colour* group. Data for the *Exemplar Colour Test* group showed significantly more colour errors across all sets compared to either of the All Colour groups suggesting that the all colour training exposures the All Colour groups received were more effective in reducing colour errors than the exemplar training received by the exemplar training groups (*Exemplar All Colour* and *Colour Test* groups). The *Exemplar Colour Test* group produced a decrease in colour errors in exposure 2 compared to exposure 1 for all stimulus sets. However, these decreases were not maintained in exposure 1 of the second or third stimulus set showing that the participants required exemplar training to "ignore" the competing non-arbitrary colour relation. Colour errors for the *Repeat Colour Test* group remained high across both exposures in all the sets.

Neutral errors for both of the All Colour groups decreased sharply across testing exposures and reached near zero level for both All Colour groups during exposure 2 of the third stimulus set. Neutral errors for the *Repeat Colour Test* group remained high across all stimulus sets suggesting that the presence of a competing non-arbitrary stimulus relation during testing interfered with the formation of the trained arbitrary relation and participants in this group were unable to consistently respond according to either the non-arbitrary or trained equivalence relation during a significant number of testing exposures.

One possible criticism of the current experiment relates to the efficacy of exemplar training. The findings indicated some improvements with repeated exposure to the test in the absence of any form of C-A training, although the improvements in equivalence were not as large as those with explicit training. However, future research might involve a greater number of exposures to repeated testing in order to determine the impact of particular numbers of exposures on equivalence.

It could be argued that some of the effects reported in the current experiment may have been a function of the point in the procedure in which the explicit C-A training was located. One possible suggestion for future studies would be to place the explicit C-A training immediately prior to another C-A test. This modification might facilitate a more systematic analysis of the effects of the explicit training on derived equivalence performances immediately thereafter. Future researchers might consider this issue in designing further studies of this type.

Although the current work clearly replicated and extended the study by Stewart et al., (2002), it continues to suffer from some of the weakness highlighted by these researchers in the original study. For example, tests of derived symmetry relations were not included in the current protocol and this may have had a notable impact on the derivation of symmetry. Perhaps, for example, equivalence performances of some participants would have been better with the inclusion of symmetry tests prior to the equivalence test. Other researchers have indeed highlighted the importance of the equivalence test sequence in generating strong equivalence performances (Adams, Fields, & Verhave, 1993). Future research will be needed to isolate the critical variables in the training and testing of equivalence. The findings of this work could then be extended to investigate how these variables affect equivalence performances in the presence of non-arbitrary and other types of derived relations.

The design of the current experiment has eradicated some arguments that may have been forwarded in response to the procedures involved in the Stewart et al. (2002) study. For example, it may have been argued that the effects produced in the original study would disappear with an experimental design that produced robust emergence of untrained relations. The findings with regard to the explicit equivalence (C-A) training procedure incorporated into the current experimental design produced improvements in equivalence but differences among the conditions remained. This effect was also consistent across the three sets of exemplars lending more weight to the argument that the reported effects would not disappear should such an experimental design be introduced.

Another important area for possible expansion of the current work would be to determine if these findings could be replicated with different populations. The current experiment, as with Stewart et al. (2002), was conducted with verbally-sophisticated undergraduate students. The research work in future chapters will use some of the procedures from this experiment to test younger populations, who, for example, might show greater influence of the non-arbitrary relations. Further studies will also be conducted with children with a diagnosis of autism. Individuals diagnosed as having autism are frequently characterised by perseverative tendencies, and thus the research will investigate whether such tendencies would manifest themselves in a high level of interference by the non-arbitrary relations.

In summary, this experiment has demonstrated that introducing non-arbitrary relations into equivalence test procedures may result in significant interference with equivalence performances. The results also suggest that an exemplar training procedure may be useful in remediating this interference effect. Subsequent studies will investigate this effect with normally developing children and children diagnosed with autism.

Chapter 3

CHAPTER 3

Competing Arbitrary and Non-arbitrary Relational Responding in Normally Developing Children

The experiment presented in Chapter 2 of the present thesis reported that the presence of competing non-arbitrary stimulus relations interfered with derived equivalence responding in language-able adults. The aim of the experiment presented in the current chapter was to determine if conflicting non-arbitrary relational responses would disrupt equivalence class formation in normally-developing young children. Previous research has reported that normally developing children readily demonstrate equivalence-class formation from a very young age if exposed to conditional discrimination training (e.g., Luciano, Becerra, & Valverde, 2007; Lipkens, Hayes, & Hayes, 1993). However, no previous research has sought to determine if competing non-arbitrary stimulus relations interfere with equivalence class formation in children.

As discussed in Chapter 1, the Colour-Test procedures developed by Stewart et al. (2002) share many features of tests traditionally used to assess EF. Interestingly, previous research examining the performance of children in tests of EF has found that children's performances vary widely depending on their age (Huizinga et al., 2006). Developmental studies using standard neuropsychological tasks have shown EF to have a protracted course of development beginning in early development and continuing into adolescence (Huizinga, Dolan, & Van der Molen, 2006). Young children have been reported as showing perseverative patterns of responding on the Wisconsin Card Sorting Task, and as requiring more moves to solve the Tower of London task (Baker, Segalowitz, & Ferlisi, 2001; Lehto, 2004; Welsh, Pennington &

Grossier, 1991). Research has also shown that as the children grow older and acquire more complex cognitive abilities their performance in EF tasks improve and become more flexible (Zelazo, 2004).

The performance of young children in EF related tasks improves greatly in the second year of life which has been attributed to the development of language and language use (Zelazo, 2004). However, children continue to show development in other abilities, such as the use of rules, across early childhood (Zelazo, Muller, Frye, & Markovitch, 2003). Indeed, many facets of EF continue to develop across childhood and adolescence until adulthood with different facets developing at different paces. For example, an analysis of the performance of children in the WCST shows the performance of a 12 year is comparable to that of young adults (Levin et al., 1991; Welsh et al., 1991) which suggests that set shifting abilities and switching between tasks skills are well developed by this age. Working memory, however, has been found to develop gradually across childhood and adolescence (Beveridge, Jarrold, & Pettit 2002; Brocki & Brohlin, 2004). Another interesting finding is that if the complexity of the task is increased through increasing the number of choices in the same task, children of all ages will show deficits in EF tasks they have previously mastered (Zelazo, 2004).

The Current Experiment

Considering the varying performances of young children in tests of EF reported in the literature it was felt necessary to modify the procedures used with this participant population. In designing the procedures for the current experiment, two substantive modifications were made to the automated procedures previously employed with the adult participants. First, a decision was made to shift from automated to non-automated or table-top procedures. The latter appear to offer some advantages when working with young children for whom the social interaction involved in such procedures appears to provide social reinforcement for maintaining on-task behaviour (Dymond, Rehfeldt, & Schenk, 2005). Furthermore, when the current experiments were conducted, a table-top format provided a more naturalistic learning environment than that provided by the computer-based equivalence program (i.e., the children had very limited experience with computers in an educational context). In short, a table-top format allowed the researcher to provide social reinforcement throughout the experimental sessions and the children did not need to adapt to, or learn about, a novel educational environment.

The second modification to the procedures employed with the young children was the adoption of a type of A-B-A reversal design. The decision to adopt this type of experimental design was based on three considerations. First, the amount of time and effort required to work with young children on equivalence-based tasks extends well beyond that required when working with adults, and thus it was not realistic to employ large groups of children. Secondly, the number of available children who could participate within the experiment was also limited to those attending the school within which the researcher was working. Third, and perhaps most importantly, the reversal design clearly demonstrates the impact of the critical variable, in this case the effect of non-arbitrary stimulus relations on equivalence responding. Consequently, some form of single-participant methodology was deemed appropriate for all subsequent experiments, which were conducted using children as participants.

Initially, participants were presented with a MTS training procedure using stimuli that were all presented in black (A1, B1, C1 – A2, B2, C2). Specifically, participants were taught two sets of A-B and B-C relational responses (See Fig. 10 for representation). After participants reached a criterion level of responding for the A-B and B-C relations they were tested for the untaught C-A equivalence relation again using all black stimuli (this was designated the baseline condition in the ABA reversal designed).

A1

B1 B2

Figure 10. A1 - B1 match to sample training trial.

When criterion levels of equivalence responding were reached the participant was re-exposure to the MTS training with black stimuli before being tested for C-A equivalence responding using stimuli coloured either red or green (the B component in the reversal design). In effect, this testing phase introduced competing non-arbitrary stimulus relations into the equivalence test (see Fig. 11 for representation). The design of this testing procedure was such that for two thirds of trials the “correct” comparison stimulus was a different colour to the sample stimulus while for the remaining one third the equivalent (correct) stimulus was the same colour as the sample. After participants finished the *Colour-test* condition they are re-exposed to No-Colour training and testing conditions (i.e., a return to the baseline condition).

C1

A1 A2

Figure. 11. Colour-Test condition with competing non-arbitrary relation of colour.

Method

Participants and participant identification

There were three female and one male participant employed**.** Each of the participants were pupils in a local mainstream national school in the Dublin area, and were accessing education through the national primary school curriculum in a mainstream classroom setting. Their ages ranged from 6-7 years of age. Although the children were not formally assessed for the purposes of the experiment, neither their teachers nor parents had reported any behavioural, learning or emotional difficulties with any of the children.

Stimuli and Setting

All training and testing trials were conducted individually with each participant while seated at a small table in a quiet room. Three of the participants took part in the experiment in the in the child's school environment. One participant (P3) participated in a quiet room in their home. During the training phase, each participant was taught a series of two interrelated conditional discriminations using abstract shapes (alphanumerics are used to label these shapes but participants never saw these labels). A MTS format was used for each trial. For the A-B training trials, participants were presented with either A1 or A2 as the sample stimulus with B1 and B2 as comparison stimuli. A correct response was choosing B1 in the presence of A1 or B2 in the presence of A2. For the two B-C tasks participants were presented with either B1 or B2 as the sample stimulus and the two comparison stimuli, C1 and C2. The correct response was the choice of C1 in the presence of B1 and C2 in the presence of B2 (see Figure 10).

During training trials, all of the stimuli were coloured black and appeared in bold print on white laminated paper sized 8cm by 8cm squared. Examples of the symbols used are presented in Figure 12. For each trial, the subject was presented with two comparison stimuli that were placed along the lower edge of the table, one in the left corner and the other in the right. The left and right positioning of the comparisons was counterbalanced across trials to prevent responding on the basis of stimulus position alone. The sample stimulus was then placed into the participant's hand accompanied by the verbal antecedent "Goes with?"

The materials used during the testing trials were the same as those employed during the training phase, except that the C stimuli served as samples and the A stimuli as comparisons (correct responding was defined as choosing A1 given C1 and choosing A2 given C2). Furthermore, during some test sessions the stimuli were altered from black to coloured forms (i.e., red and green). Colour was assigned to the stimuli such that one of the comparisons was always the same colour as the sample stimulus whereas the other was a different colour. The correct comparison stimulus was a different colour to the sample stimulus in 70% of presentations but was of the same colour as the sample stimulus in 30% of presentations.

Reinforcers

During the training phases of this experiment the experimenter provided the participants with consequence for their responses. If the participant responded correctly positive reinforcement was delivered in the form of verbal praise ("Well done, that's right") and small edibles, such as individual "Smarties" and the occasional small toy. The reinforcers used during the experiment were selected based on an informal assessment of the child's preferences and interests obtained via pre-experimental meetings between the child and the researcher.

Procedure

The experiment was conducted over several sessions with each child. Sessions lasted approximately 20 minutes, but no longer than 30 minutes. Testing phases were always conducted immediately after the participant had reached the appropriate training criteria. Due to practical constraints arising from the school context in which the research was conducted, it was not possible to obtain measures of inter-observer reliability (this applied to all of the experiments conducted with children). Given the exploratory nature of the research in which no formal hypotheses or predictions were made, the lack of such a measure was not deemed to be highly problematic.

Phase 1: Initial training and testing with familiar stimuli. All participants were exposed to an initial training and testing condition in which a stimulus set comprising symbols representing common objects was used (see Figure. 12 for an example of the pictures of familiar items used). This condition was used to familiarise participants with the form of the MTS trials used in the experiment; hereafter referred to as the Familiarisation Condition.

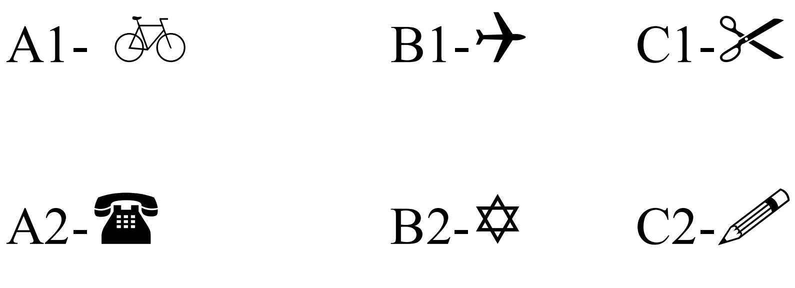

Figure 12: Pictures of common objects used in initial condition of experiment. Note that participants were not exposed to the alphanumeric labels, which are used here for communicative purposes.

The training commenced with the experimenter sitting on one side of a desk with the child sitting facing him on the other side. The experimenter started the session by showing the participant some sweets or other choice reinforcers and asking the participant “Would you like to play a game with me and earn some sweets?” All stimuli presented during the training phase were black in colour.

Linear training: Initially participants were exposed to a linear training procedure whereby each arbitrary relational response was trained in isolation until a criterion level of arbitrary responding was demonstrated. The target criterion was achieved when a participant produced 8 consecutive arbitrary relational responses within a 20-trial block. When criterion was achieved with one relation, training with the next relational response commenced. The first relation to be trained was A1-B1, followed by A2-B2 task, then by B1-C1, and finally B2-C2 training.

The training procedure of the initial A1-B1 relation involved the participant being shown the two comparison stimuli, B1 and B2, and was then presented with the sample stimulus, A1, along with the verbal antecedent “goes with”. The participant was required to put A1 with the correct comparison B1. If the participant responded correctly, the experimenter delivered verbal praise on a fixed ratio of one (FR1) and delivered edible reinforcement (or the occasional small toy) on a variable schedule.

If the participant responded incorrectly by placing the sample stimulus with the incorrect comparison, B2, the experimenter repeated the antecedent and used hand-over-hand physical guidance to place the sample over the correct comparison. This correction procedure was used for all incorrect responses during training. The right-left position of the two comparison stimuli was varied in a random fashion.

For each relation, the same training procedures were used as for the A1-B1 relation. After criterion levels of performance were achieved for each of the four relations, the mixed training phase was initiated.

Mixed training: In the mixed training phase, all four trial-types (two A-B and two B-C relations) were randomly presented within blocks of 20 trials. The mastery criterion for this training phase was set at a minimum of four correct responses out of five for arbitrary relational response (A1-B1, A2-B2, B1-C1, B2-C2). If the participant failed to achieve the set criterion for any trial type, the participant restarted the training procedures (i.e. was cycled through both Linear and Mixed training procedures). This procedure was repeated until the participant demonstrated criterion levels of arbitrary relational responding for all four responses. The participant was then deemed to have qualified for the equivalence test.

Equivalence Testing: Throughout the equivalence test, performance-contingent feedback for matching responses was not provided (the experimenter simply provided a 2-second inter-trial interval during which no direct interaction with the child occurred). Each participant was tested for equivalence responding using the same MTS task as that used during training, but the following two untrained relations were presented; C1-A1 and C2-A2. The child was presented with 10 C1-A1 trial-types and 10 C2-A2 trial-types. These two tasks were presented in a random order within 20-trial blocks.

In order to prevent response extinction due to the lack of contingent feedback during testing, after approximately every five trials (VR5) the experimenter reinforced on-task behaviour irrespective of the child's matching responses (e.g., "That's great sitting in your chair"…"That's great listening to your teacher".. etc). Any direct request by a participant for an edible or toy during the testing phase was ignored by the experimenter, who simply continued with the testing procedure.

If a participant produced a minimum of 90 percent matching responses that were consistent with the trained baseline relations (i.e., C1-A1 and C2-A2) across the

20 trials, he or she progressed to the next phase of the experiment (hereafter, relation consistent responding will be described as “correct”). If the participant failed to achieve the criterion of 90 percent correct, he or she recycled through training and testing for a second time (blocked training, mixed training, and equivalence test).

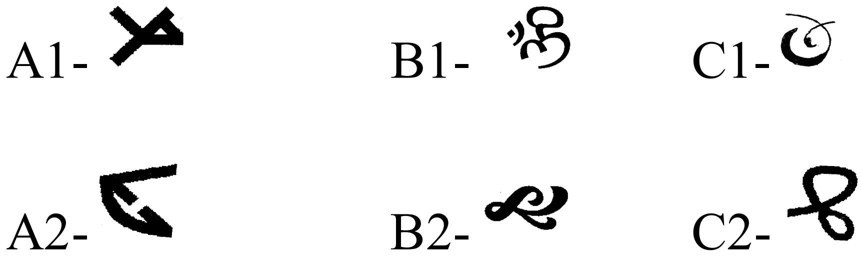

Figure 13. Symbols used in experiment. Note that participants were not exposed to the alphanumeric labels, which are used here for communicative purposes.

Phase 2: Full training and testing with novel black and coloured stimuli. During Phase 2 participants were exposed to three separate test conditions that comprised the A-B-A reversal experimental design. The three test conditions were the *No Colour 1* condition, *Colour Test* condition, and *No Colour 2* condition. The No Colour conditions respectively functioning as baseline and return to baseline test conditions. The training procedures that preceded each condition were identical to the training procedures outlined in Phase 1.

No Colour 1: In the first test condition, the *No Colour 1* condition, participants were exposed to the same sequence of training and testing described above, except that novel stimuli were employed (see Figure. 13). That is, participants were trained and tested for the formation of two three-member equivalence classes using black stimuli throughout. Participants were required to achieve the same criterion level of equivalence-consistent responding as was specified in Phase 1 (90 % equivalence consistent responding) in order to progress to the next test condition.

Colour Test: During the second test condition, the *Colour Test* condition, participants were retrained with the same stimuli again, but during the equivalence test the C and A stimuli were presented in colour, rather than in black. That is, the comparison and sample stimuli were coloured either red or green. For 70 percent of the trials, the "correct" comparison stimulus was a different colour to the sample stimulus. For example, if the sample stimulus was green in colour, then the "correct" comparison was coloured red (see Figure. 11 for representation). For these test trials, therefore, there was a conflict between the arbitrary equivalence relation that was predicted based on the trained conditional discriminations and the pre-experimentally established non-arbitrary relation of sameness (in terms of colour) between the sample and comparison stimuli. For the remaining 30% of test trials, the equivalent (correct) stimulus was the same colour as the sample.

Participants were provided with only one exposure to the equivalence test with coloured stimuli (i.e., they were not cycled between training and testing until a criterion performance was reached).

Colour Test 2: Following exposure to this single equivalence test, participants progressed to the third test condition, the *No Colour 2* condition where they re-exposed to the conditional discrimination training procedures (described previously) with the same stimuli before being re-exposed to the equivalence test again but using all black stimuli for one final exposure. Following this third cycle of training and testing with the same set of stimuli, participation in Experiment 3 was complete. An overview of the experimental sequence is presented in Figure. 14.

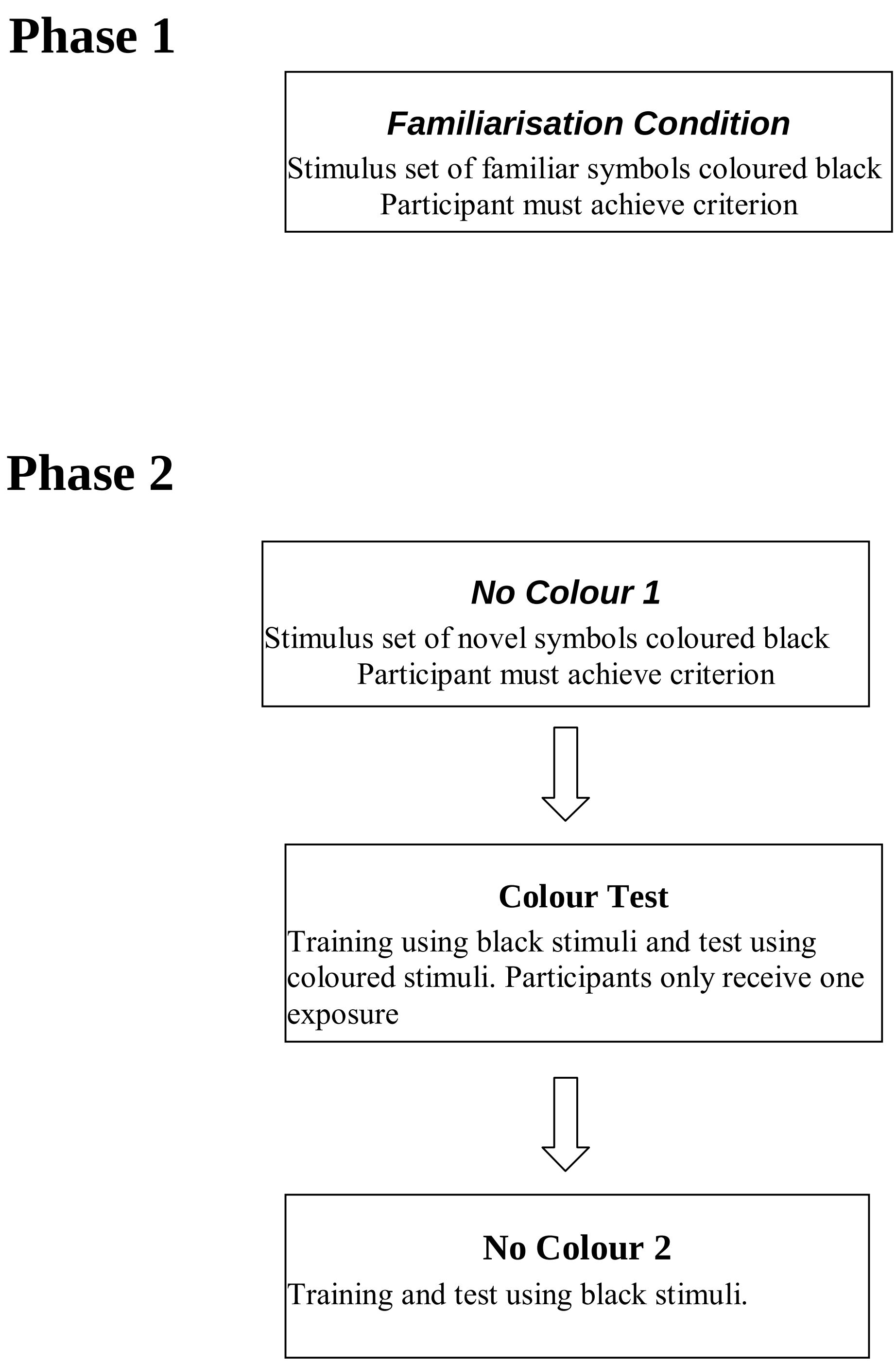

Figure 14. A schematic representation of the overview of the experimental sequence

Results

The number of training trials and number of correct equivalence responses produced by each participant across the experiment are presented in Table 3. All four participants completed the MTS training using the familiar stimuli, but then failed to reach the mastery criterion during the first equivalence test. Three participants (1, 2, & 4) did reach criterion after being re-exposed to the MTS training; P3 required a third cycle of training and testing before producing the required equivalence responding.

When novel stimuli were employed in Phase 2, Participants 1 and 2 passed the equivalence test on their first exposure, P4 on the second exposure, and P3 on the fourth exposure. During the critical *Colour Test* condition, when coloured stimuli were used during the equivalence test, all four participants maintained the equivalence response patterns observed in the previous test exposure. That is, the introduction of coloured stimuli and competing non-arbitrary sameness relations appeared to have little impact on the equivalence responding. During the final training and testing, *No Colour 2*, all four participants again maintained the previously established equivalence responding.

Overall, therefore, the current findings showed that all four children demonstrated equivalence responding after two or three cycles of training and testing with a set of familiar stimuli. Equivalence responding was also observed for all participants when novel stimuli were employed, although between 1 and 4 cycles of training and testing were needed. When the coloured stimuli were introduced (*Colour Test*) and subsequently removed (*No Colour 2*) this had virtually no impact on the participants' equivalence responding. The findings are in clear contrast to the data obtained from the adult participants reported in the previous chapter. Specifically, introducing non-arbitrary stimulus relations that were designed to interfere with equivalence responding clearly effected adult performances, but had little impact on the young children employed in the current experiment.

Table 3. Number of training trials and number of correct responses during test blocks for each participant:

Training and Test Blocks		Participant 1	Participant 2	Participant 3	Participant 4
Phase 1- Familiarisation Condition					
	Train	51	53	55	57
	Test	11/20	13/20	3/20	15/20
	Train	49	48	48	49
	Test	**19/20**	**20/20**	15/20	**20/20**
	Train			52	
	Test			**19/20**	
Phase 2					
No	Train	57	51	53	58
Colour1	Test	**18/20**	**20/20**	0/20	13/20
	Train			48	49
	Test			12/20	**20/20**
	Train			49	
	Test			17/20	
	Train			49	
	Test			**19/20**	
Colour	Train	48	54	48	48
Test	Test	**20/20**	**20/20**	**18/20**	**19/20**
No	Train	48	48	48	50
Colour2	Test	**20/20**	**20/20**	**20/20**	**19/20**

Discussion

The primary objective of the present experiment was to examine the effects of conflicting non-arbitrary stimulus relations on the formation of arbitrarily applicable relational responding in young children. The data showed that for all four participants the presence of a competing non-arbitrary colour relation in the *Colour Test* condition did not interfere with equivalence-consistent responding. These results are not consistent with the findings of both Stewart et al. (2002) or the results reported in Chapter 2 of the present thesis. Both of those experiments found that the presence of a competing non-arbitrary colour relation disrupted derived equivalence responding in adults. How might we account for this discrepancy?

Perhaps the most likely explanation is the fact that so many modifications were made to the MTS training and testing procedures for the children. For example, only two comparison stimuli were presented on each trial, and two three-member equivalence classes were induced; for the adults, however, three comparisons were presented and three, three-member classes were the target. Furthermore, a table-top procedure was employed with the children, whereas the adults completed the MTS training and testing on a computer. In addition, the children were first required to demonstrate equivalence responding with familiar stimuli and with the critical novel stimuli before being exposed to the equivalence test using coloured stimuli. In contrast, the adults were not required at any stage to produce criterion levels of equivalence responding in order to proceed to the next stage of testing. Overall, therefore, perhaps the superior equivalence performance of the children is not that surprising. Relative to the adults, the MTS training and testing involved fewer stimuli, provided additional sources of social reinforcement via on-task social interaction with the experimenter, and required participants to produce the target performance before the interfering stimulus relations were introduced.

At this point in the research programme one option for future experiments would be to explore the extent to which each of the aforementioned variables were critical in producing such robust equivalence-consistent performances in young children. However, another approach could involve exploring the use of the procedures developed for the present experiment with participant populations who historically have shown poor performance in tests of executive function. Based on the material covered in the introductory chapter, it is possible that such participant populations might show greater influence of the non-arbitrary relations between stimuli than was evident with the present participants. Thus, further experiments could be conducted with children diagnosed with autism who have been shown by past research to demonstrate perseverative patterns of responding (Turner, 1999; Mc Evoy et al. 1993). The following series of experiments reported in the remainder of the current thesis thus employed children diagnosed with autism. Specifically, the research aimed to determine if such perseverative tendencies would manifest themselves in a high levels of interference by the non-arbitrary relations on the formation of derived equivalence relations, and if so how best to remediate that interference.

Chapter 4

Chapter 4

Competing Arbitrary Relations and Non-Arbitrary Relational Responding in Children Diagnosed with Autism.

The studies presented in Chapters 2 and 3 of the present thesis have built on the findings of Stewart et al. (2002), whose results showed that the presence of competing non-arbitrary relations between stimuli interfered with the formation of derived arbitrary relational responding in a participant population of language-able adults. In Chapter 3, the MTS procedures developed by Stewart et al. were modified to make them applicable for a participant population of young children and the results demonstrated that the modified procedures were effective in teaching participants to respond according to the taught arbitrary relations during training. The data from the testing conditions also reported that all participants produced robust derived equivalence responding during all conditions. Most interestingly, results also demonstrated that all participants maintained high levels of equivalence responding during the *Colour Test* condition suggesting that the modified procedures undermined control by the competing non-arbitrary relations.

As noted at the end of the previous chapter, the research reported in the current thesis will focus on using the procedures developed thus far to investigate the extent to which children diagnosed with autism would be susceptible to interference by non-arbitrary stimulus relations during an equivalence test. To justify the use of this particular population it seems important to consider why children with autism would be likely to demonstrate interference from non-arbitrary stimulus relations.

Autism Spectrum Disorder

The term autistic disorder was first used by Leo Kanner (1943) to describe a group of 11 children who displayed a number of unique characteristics and symptoms not seen in other populations of children with a learning disability. In a groundbreaking article Wing and Gould (1979) characterised autism as consisting of a triad of impairments in the domains of socialisation, communication, and imaginative play. Internationally accepted handbooks such as the ICD-10 (World Health Organisation 1992) and the DSM-IV (American Psychiatric Association 1994) have standardised these criteria for the diagnosis of autism. Using these criteria, population studies have shown that autism affects at least 0.6% of individuals at a male: female ratio of 3:1 (Hill & Frith 2003).

There have been many recent attempts in the field of autism research to examine the link between symptomology and cognitive impairment in order to identify causal factors in the onset of autism in children at a young age (Turner 1997). While much disagreement remains as to the core characteristics of autism, recent research has focused on the functionalism of language and socio-cognitive characteristics unique to autism (Rogers & Loisa Benneto, 2000). Scores on IQ tests have been shown to remain stable over time in individuals with a diagnosis of autism (Freeman et. al, 1991), and attention, associative memory, and rule learned abstractions have been identified as areas of relative strength (Minshew et al. 1992). However, individuals with a diagnosis of autism have been shown to struggle in tasks that require abstraction involving cognitive flexibility, verbal reasoning, complex memory, and complex language (Minshew et al, 1992). Autism is also associated at all levels of ability with deficits in conceptual problem solving, meta-representational ability, pragmatic elements of communication, joint attention, symbolic play, and the recognition of emotions (Jordan, 1995).

One theory that attempts to explain the deficits associated with autism is known as the Executive Dysfunction Hypothesis (EDF). Executive function (EF) has been defined as "the ability to maintain an appropriate problem solving set for attainment of a future goal" (Welsh & Pennington, 1988, p. 201) and is used to describe brain based skills that begin to develop in the first years of life. The EDF theory argues that there is a severe, early disruption in the planning of complex behaviour, due to a deficit in working memory (Pennington et al. 1997). As this deficit occurs very early in development, it disrupts not only the planning of behaviour, but also the acquisition and use of concepts that require the integration of information within a context and across time. This would account for the observed deficits in social and communication behaviours such as joint attention, imitation, theory of mind and symbolic play that are associated with autism (Pennington et al. 1997).

Executive dysfunction is reported as being pervasive in children with autism (Pennington & Ozonoff, 1996; Pennington et al., 1997), and effected individuals have also been found to demonstrate poor abstract reasoning, inflexible rule use, preservative behaviours, cognitive inflexibility and poor attention (Pennington & Ozonoff, 1996). In a review of studies in this area, Pennington and Ozonoff (1996) found that individuals with autism performed significantly poorer than control populations in 25 of 32 EF tasks across 14 studies. Researchers have identified four dimensions encompassed under EF which are "inhibition", "cognitive flexibility", "working memory" and "planning" (Pennington 1997). Individuals with a diagnosis of autism have shown a deficit in cognitive flexibility across a number of studies

(Pennington et al. 1997) with participants showing an inability to shift set in such tasks as the Wisconsin Card Sorting Task (Ozonoff, 1995b), and the spatial reversal task (McEvoy et al. 1993). Other studies have shown that individuals with autism performed more poorly than normative controls in sorting objects according to shape or colour or in the classification of objects according to categories (Sigman et al. 1987). Populations diagnosed with autism have also been found to produce more preservative errors in EF tasks (Mc Evoy et al. 1993). Indeed, Turner (1999) found that children with autism showed an inability to self cue themselves to respond correctly in fluency tasks and showed higher levels of perseveration in their responding. Most interesting in the context of the present research is the finding that participants with a diagnosis of autism show lower levels of responding relative to controls in tasks containing a competing "proponent response" and tasks that contain arbitrary rules (Ozonoff, Pennington, & Rogers, 1991; Hughes, Russell, & Robbins, 1994; Biro & Russell, 2001). Proponent responses "are erroneous responses that are called out" either by some salient feature of the environment or by some features rendered salient through previous learning" (Biro & Russell, 2001 pp. 98).

The remainder of this chapter comprises two studies investigating the use of the MTS procedures outlined in the Chapter 3 with a participant population of children diagnosed with autism. Specifically, these studies will seek to determine if children with autism are susceptible to interference from non-arbitrary stimulus relations in the context of demonstrating equivalence class formation. Insofar as children with autism find it difficult to complete tasks that require the use of arbitrary rules, this population should also find it difficult to acquire arbitrary stimulus relations, especially when a competing non-arbitrary basis for responding is present.

Experiment 3

Introduction

This Experiment will present one participant diagnosed with autism with an MTS procedure that is somewhat reduced relative to that presented in Chapter 3 of the current thesis. The primary purpose of this initial experiment was to address the criticism of the procedures used in Chapter 3 that produced highly robust levels of equivalence responding. Specifically, it could be argued that the use of the initial familiar stimulus set in Phase 1 of the experiment, and the criterion performance requirement with black stimuli, provided participants with a learning history that completely undermined the potential interference from subsequent non-arbitrary relations. Thus, in this first experiment the participant was not exposed to the familiar stimuli (Phase 1), and was not required to demonstrate equivalence class formation when the stimuli were presented in black.

Method

Participants and participant Identification

The participant in this experiment was a five year old boy with a diagnosis of autism. The child was attending the ABACAS School Kilbarrack, a school devoted to the education of children with autism through the use of applied behaviour analysis. The participant was assessed using the PIRK assessment tool. This is a criterion-referenced instrument for assessing the repertoires of verbal behaviour acquired by pre-school children (Greer, Mc Corkle, & Twyman, 1996). The PIRK categorises repertoires that the individual child will need to master according to the conceptual scheme found in Skinner's Verbal Behaviour (1957). Within each subdivision of the PIRK's curricular sequence tasks move from less complex to more complex, such that, each higher number is an advancement in competency and the preceding numbers are pre-requisites to the more complex task in most cases. These categories are:

1. Pre-listener
2. Listener/ pre-speaker
3. Speaker/ pre-conversational
4. Speaker as own listener
5. Reader
6. Reader-writer
7. Self-editor

For illustrative purposes, a child would be assessed as possessing a reader repertoire if s/he can produce reading behaviour in the context of a task that requires such behaviours. The participant in the current experiment was assessed as having reader-writer emergent self-editor repertoires of verbal behaviour. That is, he had functional reader and writer skills and possessed early but incomplete behavioural repertoires for the editing of his own verbal behaviour.

Stimuli and Setting

The setting used to work with the participant was identical to that used in the experiment presented in Chapter 3. However, in the present experiment the participant was not exposed to the Familiarisation Condition which used a stimulus set of symbols depicting familiar items (i.e., only the set of novel symbols used in Phase 2 of the previous experiment were used in the current experiment).

Reinforcers

During the training phases of the current experiment, the researcher provided the participant with consequences for his responses. If the participant responded correctly, positive reinforcement was delivered in the form of verbal praise (“Well done, that's right") and small edibles, such as individual "Smarties" and the occasional small toy, were delivered. The reinforcers used during this experiment were those used during the participant's typical school day. They had been established for the participant prior to the onset of the experiment and were specified by the preferences and interests of the participant. In the ABACAS system students gain access to positive reinforcers contingent on correct responding according to schedules individualised to the needs of each student. For example, a student gains access to secondary reinforcement on a VR3 schedule of 3 correct responses. The schedules used with the participant in this experiment were similar to those used during their educational programmes on a normal school day.

Procedure

The procedures used in this experiment are similar to those used in the experiment presented in Chapter 3 of the current thesis. However, the participant in the current experiment was not exposed to the stimulus set of familiar symbols used in Phase 1. In the current experiment the participant started training and testing procedures with the stimulus set of novel symbols using procedures similar to those outlined in Phase 2 of the experiment in Chapter 3. The participant was required to demonstrate the criterion levels of arbitrary relational responding employed in the previous experiment (i.e. Demonstrate 8 consecutive arbitrary relational responses in 20 training presentations during Linear training; demonstrate 4 arbitrary relational responses out of 5 presentations during Mixed training).

However, the participant was *not* required to achieve a criterion level of equivalence responding in the *No Colour 1* test condition in order to progress to the *Colour Test* condition. Finally, unlike Experiment 3, the participant was exposed to two cycles through the three separate conditions. Therefore, unlike the participants in

Chapter 3, the participant in the current experiment would complete two exposures to the *Colour Test* and *No Colour 2* test conditions. The purpose of this alteration in the training and testing procedure was to examine if equivalence-consistent responding would be increases through repeated testing exposures.

Results

Table 4. Number of training trials and number of correct responses during test blocks:

Exp Condition	MTS	Exp 1	Exp 2	Exp 3	Exp 4	Exp 5	Exp 6
Train	Linear	42	46	47	35	36	49
	Mixed	16/20	12/20	9/20	12/19	13/18	11/19
No Colour 1	Linear	33					
	Mixed	16/16					
	Test	**10/20**					
Colour Test	Linear	37					
	Mixed	16/18					
	Test	**4/20**					
No	Linear	32					
Colour 2	Mixed	16/16					
	Test	**12/20**					
2^{nd} Cycle							
Train	Linear	35					
	Mixed	14/20					
No	Linear	32					
Colour1	Mixed	16/16					
	Test	**7/20**					
Colour	Linear	35					
Test	Mixed	16/17					
	Test	**1/20**					
No	Linear	35					
Colour2	Mixed	16/16					
	Test	**9/20**					

The results for training and testing are shown in Table 4. The participant achieved criterion levels of arbitrary relational responding during the linear training phase of the MTS procedure and qualified for the mixed training phase in all exposures. However, the participant required seven training exposures to reach criterion levels of arbitrary relational responding in the mixed training phase. The participant produced criterion levels of arbitrary relational responding and qualified for the testing condition in each of the three conditions during the first cycle.

The participant failed in each of the three test conditions to produce evidence of equivalence class formation, responding at around chance level in the *No Colour 1* and *No Colour 2* conditions, and producing only 4 equivalence-consistent responses in the *Colour Test* condition. Because the participant had not been required to produce equivalence responding during the *No Colour 1* condition, he was exposed to a second cycle of testing to determine if equivalence responding would emerge following additional exposures. However, the number of equivalence-consistent responses actually dropped during this second exposure across each of the three conditions.

The data for the errors produced by the participant during both of the *Colour Test* testing conditions is presented in Table 5. There were a consistent number of colour matching errors during both exposures to the *Colour Test* condition (15 and 14, respectively). The number of neutral errors increased from 1 to 5 across the two exposures.

Table 5. Participants number of error responses during Colour Test condition exposures.

Exp#	Number of errors during *Colour Test* condition	Neutral errors	Number of colour response errors during *Colour Test* condition
1	16	1	15
2	19	5	14

Discussion

Results from the training phase of the current experiment indicate that the MTS training procedure was effective in teaching the participant to respond according to the trained arbitrary relations. However, while that participant successfully qualified for the testing conditions, the level of errors in all testing conditions remained high. Furthermore, the participant produced fewer equivalence-consistent responses in the *Colour Test* conditions relative to the *No Colour* test conditions.

Interestingly, low levels of derived equivalence responding were observed in all test conditions, with less than fifty percent of responses in accordance with equivalence in the majority of test conditions. Significant numbers of errors in the *No Colour* testing conditions occurred in the absence of a competing non-arbitrary colour relations between the stimuli. Although the lower levels of equivalence responding in *Colour Test* conditions suggest an interference effect for the competing non arbitrary relations, the high numbers of errors across all conditions suggest that other factors may potentially be involved.

Given the lack of equivalence responding across all conditions in the current experiment, it appears that that the modifications used in the current experiment more or less undermined the relatively robust equivalence-generating effects observed with the normally developing children. On balance, however, the single participant employed in the current experiment was diagnosed with autism, and thus it is possible that the much poorer performance observed here was due to this diagnosed condition. In the next experiment, the original procedures employed in the previous chapter were used with a series of children diagnosed with autism in order to determine if they would demonstrate equivalence responding in the *No Colour* conditions, but also show evidence of interference from the non-arbitrary relations during the *Colour Test* conditions.

Experiment 4

Introduction

The result of Experiment 3 in the current chapter demonstrated that a participant diagnosed with autism failed to demonstrate equivalence class formation with a modified version of the procedures reported in the previous chapter. The current experiment will employ those previous procedures, which involve training and testing during the *No Colour* conditions until the participant has demonstrated equivalence class formation. Only after equivalence classes have been formed with a set of stimuli will participants then be exposed to the *Colour Test* condition. The key aim of this experiment was to determine if participants diagnosed with autism will show evidence of interference from the non-arbitrary stimulus relations.

Method

Participants and participant identification

There were six participants in the experiment, four male and two female**.** Participant 1 was the child who had completed Experiment 3. Each of the participants had a diagnosis of autism. Their ages ranged from 5-7 years of age. Five of the six participants were attending the ABACAS School Kilbarrack, while the sixth was a pupil in the ABACAS School Drogheda. As was the case with Experiment 3, all the participants were assessed using the PIRK assessment tool. All participants in the experiment produced similar results indicating very similar repertoires of verbal behaviour. That is, they were assessed as possessing functional reader and writer skills and possessed early but incomplete behavioural repertoires for the editing of their own verbal behaviour.

Stimuli and Setting

The stimuli and setting used in the present experiment were identical to those used in the experiment presented in Chapter 3.

Reinforcers

The reinforcement procedures and schedules used in the present experiment were similar to those used in Experiment 3 of the current Chapter. All participants received access to reinforcing items of their own choice and received reinforcement on a schedule that matched the schedules of reinforcement of a typical school day.

Procedure

The procedures used in this experiment were identical to those used in Chapter 3 of the current thesis. All six participants were cycled through both phases of the procedure.

Results

The number of training trials and number of correct equivalence responses produced by each participant during Phase 1 and Phase 2 of the current experiment are presented in Table 6. In Phase 1 five of the six participants exposed to the MTS training procedure qualified for the testing conditions immediately but one participant (P2) failed to meet the criterion (indicated by a dashed line in the table) and required an additional training exposure. P6 produced criterion levels of equivalence-consistent responding on the first testing exposure, but the remaining five participants required between two and six exposures to the MTS training and testing procedures to demonstrate criterion levels of equivalence with the familiar stimulus set. All participants qualified for Phase 2 of the experiment.

The data for Phase 2 of the experiment show all six participants produced criterion levels of equivalence-consistent responding in the *No Colour 1* condition, but they all required multiple exposures to the MTS training and testing procedure. The number of training trials presented to achieve criterion ranged from 686 training trials during twelve MTS exposures for P2 to 147 trials in two exposures for P6. The mean number of training trials required to produce equivalence-consistent responding across all six participants was 374.

When the participants were exposed to the *Colour Test* condition they all again completed the training, but critically five of the six participants failed to produce equivalence-consistent responding when the stimuli were presented in colour. Interestingly, P1 failed to meet the equivalence-test criterion although he had previously completed Experiment 3. On balance, this participant did produce the highest number of equivalence-consistent responses (15) out of the five participants who failed to meet the criterion.

When the participants returned to training and testing with all black stimuli (*No Colour 2*), equivalence-consistent responding returned to criterion levels for four of the participants who failed with the colour stimuli; one participant (P1) failed to reach criterion by just one response. P3 who produced equivalence-consistent responding during the *Colour Test* condition, unexpectedly fell below criterion, but only by two responses.

Table 6. Number of training trials and number of correct responses during test blocks for each participant in Phase1 of Experiment 4:

Exposure #		P 1	P 2	P 3	P 4	P 5	P 6
Familiarisation Condition	**Phase 1**						
1	Train	51	64	55	53	60	50
	Test	16/20	-----	3/20	17/20	11/20	**20/20**
2	Train	48	50	48	49	57	
	Test	**19/20**	14/20	15/20	**20/20**	16/20	
3	Train		48	52		66	
	Test		17/20	**19/20**		10/20	
4	Train		48			51	
	Test		**19/20**			11/20	
5	Train					48	
	Test					17/20	
6	Train					48	
	Test					**19/20**	
No Colour 1	**Phase 2 - Novel Stimulus Set**						
1	Train	51	64	65	58	58	50
	Test	12/20	12/20	------	12/20	------	2/20
2	Train	51	52	50	52	77	49
	Test	14/20	------	9/20	15/20	10/20	17/20
3	Train	48	35	49	55	62	
	Test	17/20	19/20	12/20	11/20	9/20	
4	Train		60	50	48	53	
	Test		11/20	15/20	13/20	13/20	
5	Train		66	49	49	53	
	Test		9/20	16/20	13/20	17/20	
6	Train		66	48	53	52	
	Test		9/20	14/20	13/20	17/20	
7	Train		60	51	48		
	Test		9/20	16/20	14/20		
8	Train		56	48	48		
	Test		15/20	17/20	17/20		
9	Train		61				
	Test		14/20				
10	Train		58				
	Test		11/20				
11	Train		56				
	Test		17/20				
	Train	48	52	48	48	49	48
	Test	**19/20**	**19/20**	**20/20**	**19/20**	**20/20**	**20/20**
Colour Test	Train	51	48	48	48	49	48
	Test	**15/20**	**9/20**	**19/20**	**7/20**	**9/20**	**6/20**
No Colour 2	Train	54	52	48	48	48	48
	Test	**17/20**	**19/20**	**16/20**	**18/20**	**19/20**	**20/20**

Error analysis

Table 7 presents the total number of errors made by each participant in the *Colour Test* condition, and the number of those errors that involved matching a comparison stimulus that was the same colour as the sample stimulus (i.e., colour-matching). For the five participants who failed to reach criterion, the majority of errors involved colour-matching. P3 only produced one error but this error also involved colour-matching.

Table 7. Number of error responses and number of colour matching errors during *Colour Test* condition for all participants.

Participant	Number of errors during Colour Test condition	Number of colour response errors during Colour Test condition
1	5	4
2	11	10
3	1	1
4	13	11
5	11	9
6	14	14

Discussion

The results of the current experiment showed that all six participants achieved criterion levels of arbitrary relational responding during training and produced relatively robust levels of derived equivalence responding during the *No Colour* conditions. However, five of the six participants produced lower levels of equivalence-consistent responding in the *Colour Test* condition relative to those demonstrated in the *No Colour 1* and *No Colour 2* conditions. These results demonstrate that the procedures were relatively effective in producing derived relational responding in a participant population diagnosed with autism when training and testing occurred with stimuli coloured only black. However, when a competing non-arbitrary colour relation was introduced in the *Colour Test* condition, participant tended to demonstrate weaker or completely disrupted equivalence responding. The error data indicate that the introduction of the non-arbitrary relation of colour was perhaps the main variable responsible for the majority of errors during the Colour Test condition. Only one of the participants failed to show the “disruptive” effect (P3), but at the current time the reason for this difference remains unclear. Nevertheless, the test performance obtained from P3 suggests that children diagnosed with autism may not always succumb to control by non-arbitrary relations in the context of equivalence testing, and thus there may be some value in investigating methods for remediating this “deficit.” The remaining Chapters of the current thesis present a series of studies that focused on this very issue.

Chapter 5

CHAPTER 5

Undermining Competing Sources of Non-Arbitrary Stimulus Control Using Exemplar Training

The results reported in the previous chapter demonstrate that a competing non-arbitrary stimulus relation can have a highly disruptive effect on equivalence class formation in children diagnosed with autism. As noted previously, however, one participant failed to show this disruptive effect and thus it seems wise to investigate methods for undermining this phenomenon. One general approach that has proved useful in remediating spurious stimulus control is the use of multiple-exemplar training (Engelman & Carnine, 1982). The basic concept involves reinforcing the targeted responses across a number of suitable exemplars, thereby extinguishing inappropriate forms of stimulus control, and allowing the targeted response class to emerge and come under the control of the programmed contingencies. Given that the disruption to equivalence responding reported in the previous chapter may be interpreted as a form inappropriate stimulus control, perhaps this “deficit” may be remediated using a form of multiple exemplar training. Indeed, as pointed out in the introduction to the present thesis, exemplar training is an important historical context for equivalence and derived relational responding more generally (Hayes, Barnes-Holmes, & Roche, 2001). Certainly, as previously reviewed, there is growing evidence in the literature to support this claim (Barnes-Holmes, Barnes-Holmes, Roche & Smeets, 2001a, 2001b; Barnes-Holmes, Barnes-Holmes, Smeets, Strand & Friman 2004; Barnes-Holmes, Barnes-Holmes & Smeets, 2004; Luciano et al. 2007; Berens & Hayes 2007). Taken together the results of these experiments lend considerable support to the view that exemplar training constitutes a powerful tool in establishing repertoires of derived relational responding.

Research examining the role of exemplar training in the development of equivalence responding among participants with language delay or those with minimal language repertoires provides more evidence for the central role of exemplar training in the establishment of derived relational responding. While, previous research has demonstrated it is possible to induce equivalence responding in very young children from the age of 23months and 20 days (Lipkens, Hayes & Hayes 1993), one recent study has demonstrated equivalence responding in an infant of 15 months 24 days following the use of exemplar training (Luciano et al. 2007).

Experiments investigating the formation of equivalence responding in participant populations with developmental delay have shown that individuals with severe language delay fail to demonstrate derived relational responding when compared to normative participants or participants with more developed verbal repertoires (Devany, Hayes & Nelson 1986; Barnes, McCullagh, & Keenan 1990). However, another study has shown that, with significant training, participants with developmental delay can demonstrate equivalence (Carr, Wilkinson, Blackman, & MvIlvane 2000; Sidman 1971). A number of studies have also demonstrated the effectiveness of exemplar training procedures in establishing derived relational responding repertoires in populations of children diagnosed with autism (Murphy, Barnes-Holmes & Barnes-Holmes, 2005; O' Connor, Rafferty, Barnes-Holmes & Barnes-Holmes, 2009; O' Toole, Barnes-Holmes, Murphy, O' Connor, & Barnes-Holmes, 2009; Gorham, Barnes-Holmes, Barnes-Holmes & Berens, 2009).

The experiment in Chapter 2 of the present thesis reported that language-able adults exposed to exemplar training with coloured stimuli (i.e., the participants in the

Exemplar All Colour group) showed higher levels of equivalence-consistent responding than participants in the other three groups (*Repeat All Colour, Repeat Colour Test, Exemplar Colour Test* groups). However, participants who received training with coloured stimuli (*Exemplar All Colour* and *Repeat All Colour* groups) produced more robust equivalence responding than participants who received training with black stimuli but were tested with coloured stimuli (*Repeat Colour Test* and *Exemplar Colour Test*); this also applied to those participants that were exposed to exemplar training with black stimuli (*Exemplar Colour Test*). These results suggest that exemplar training combined with coloured stimuli could be an effective intervention for increasing equivalence-consistent responding in the presence of a competing non-arbitrary relational response. The experiments reported in the current chapter investigate the effectiveness of exemplar training procedures with coloured stimuli in teaching children with a diagnosis of autism equivalence-consistent responding in the presence of a competing colour relation.

Experiment 5

Introduction

The current Experiment sought to examine the effectiveness of exemplar training derived from the procedures used with the *Exemplar All Colour* group in Chapter 2. Participants received training with a set of novel stimuli that were identical to those used in Experiments from previous chapters with the exception that the stimuli were now coloured either red or green. The aim of this Experiment was to examine the effect on participants with autism of being explicitly taught to “ignore” colour before being tested for equivalence class formation in the presence of a competing non-arbitrary colour relation.

Method

Participants and Participant Identification

This experiment exposed five of the six participants from Experiment 4 in the previous chapter to a MTS procedure using coloured stimuli. Participant 3 from the previous experiment was excluded from the current experiment because she did not demonstrate weaker equivalence responding in the *Colour Test* condition. There were four males and one female participant in the present experiment and their ages ranged from 5-8 years of age.

Stimuli and Setting

All participants took part in the present experiment in identical settings to those described in experiments presented in Chapters 3 and 4. The stimuli used in the present experiment comprised the set of novel symbols that was used in Experiment 4 of Chapter 4. In the present experiment, however, the stimuli were presented in colour during the training phases of the Experiment and during the *Colour Test* conditions.

Reinforcers

The reinforcement procedures and schedules used in the present experiment were identical to those used with the same participants in the experiments presented in Chapter 4. All participants received access to reinforcing items of their own choice and received reinforcement on a schedule that matched the schedules of reinforcement of a typical school day.

Procedure

Training procedures: The procedures used in the present experiment are similar to those used in Experiment 4 except that participants were not exposed to the

Familiarization Condition employed in Phase 1 of that experiment. All participants commenced with the stimulus set of novel symbols used in the experiments presented in Chapters 3 and 4 (see Fig. 13 in Chapter 3 for representation). Another difference between the current experiment and the previous experiments is that the stimuli used during the training phases were coloured either red or green. Colour was assigned to the stimuli such that one of the comparisons was always the same colour as the sample stimulus whereas the other was a different colour. The correct comparison stimulus was a different colour to the sample stimulus in 70% of presentations but was of the same colour as the sample stimulus in 30% of presentations. This ensured that consistently matching or mismatching colours alone would fail to produce a criterion level training performance (see Figure 16. for representation).

Participants were exposed to both blocked and mixed training conditions and all participants qualified for the testing phases of the Experiment when they demonstrated the same criterion levels of arbitrary relational responding as were applied in the experiments presented in the previous chapters.

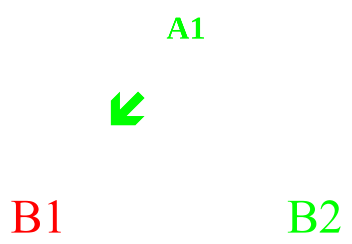

Figure 16. Colour-Test condition with competing non-arbitrary relation of colour.

Equivalence testing procedure: All participants proceeded to an equivalence testing phase that was identical to that used during the *Colour Test* conditions in the experiments presented in Chapter 3 and 4. As was the case in the previous experiments, the participants were required to demonstrate a criterion level of equivalence responding in the initial testing condition prior to advancing to the other testing conditions. However, in the current experiment participants were required to demonstrate criterion levels of equivalence responding in testing conditions with coloured stimuli. If a participant failed to demonstrate criterion levels of equivalence responding during the *Colour Test 1* condition they were recycled through training and testing with coloured stimuli until criterion was achieved.

When a participant achieved criterion during the *Colour Test 1* testing condition he or she were then re-exposed to colour training followed by a testing condition with black stimuli that was identical to the *No Colour* testing conditions of the Experiments 3 and 5 reported in previous chapters. That is, participants were trained with colour stimuli but were tested using black stimuli. After the *No Colour* condition was completed, participants were recycled through one more exposure of training and testing with coloured stimuli, the *Colour Test 2* condition.

Results

The data for the training and testing exposures for each participant is presented in Table 8. All five participants demonstrated criterion levels of arbitrary relational responding and qualified for the testing condition, although P2 required six training exposures to qualify for testing.

Participants 4, 5, and 6 produced criterion levels of equivalence responding in their first testing exposure (*Colour Test 1* condition) while P1 only required two training and testing exposures. Interestingly, P2 needed 16 cycles to produce criterion levels of responding which is significantly more exposures than was required by any of the other participants.

All five participants produced high levels of equivalence-consistent responding during the *No Colour* and *Colour Test 2* conditions, with criterion levels of responding being maintained in both. There was no substantive difference in the levels of equivalence responding across the conditions for any of the participants.

Table 8. Number of training trials and number of correct responses during test blocks using stimuli coloured either red or green in Experiment 5:

Exp#		P 1	P 2	P 4	P 5	P 6
Colour Test 1	**Stimulus Set from Previous Experiment**					
1	Train	49	64			
	Test	17/20	-------			
2	Train		72			
	Test		------			
3	Train		50			
	Test		------			
4	Train		54			
	Test		------			
5	Train		58			
	Test		------			
6	Train		65			
	Test		8/20			
7	Train		52			
	Test		17/20			
8	Train		73			
	Test		9/20			
9	Train		62			
	Test		14/20			
10	Train		66			
	Test		14/20			
11	Train		71			
	Test		13/20			
12	Train		64			
	Test		12/20			
13	Train		74			
	Test		11/20			
14	Train		53			
	Test		12/20			
15	Train		48			
	Test		16/20			
16	Train	49	50	48	57	52
	Test	**20/20**	**18/20**	**20/20**	**20/20**	**20/20**
No Colour	Train	49	48	48	48	48
	Test	**18/20**	**19/20**	**20/20**	**20/20**	**20/20**
Colour Test 2	Train	48	48	48	48	48
	Test	**19/20**	**18/20**	**20/20**	**20/20**	**20/20**

Discussion

The results of Experiment 5 show that all of the participants achieved criterion levels of equivalence-consistent responding, and maintained it across *No Colour* and *Colour Test* conditions. Only one participant (P2) required extensive training and testing in order to achieve the criterion. In effect, training with coloured stimuli was effective in teaching participants to "ignore" colour as a salient dimension in the context of an equivalence test.

Although the current results indicate that training with colour served to undermine the previously observed interference effect from this stimulus dimension, this does not provide evidence for the effect of exemplar training as no generalisation to a novel stimulus set was required. That is, colour training was provided on the same stimulus that was used to test for equivalence-consistent responding. To determine if this history of "ignoring" colour with a single exemplar would generalise to a novel stimulus set, a further experiment was required. In the next experiment, therefore, the five participants were exposed to a second novel stimulus set. Specifically, participants were trained and tested for equivalence-consistent responding using all black stimuli until they reached criterion. Subsequently, they were re-exposed to the training and testing, but during the test phase the stimuli were presented in colour (the same procedure as Experiment 4). If the experience in the previous Experiment had functioned as an appropriate "colour-ignoring" exemplar, the introduction of colour with the second novel stimulus set should have little or no effect on the equivalence performances of the participants.

Experiment 6

Introduction

The experiment will expose the five participants from Experiment 5 to an identical MTS procedure as was used in Experiment 4 of Chapter 4. However, a new set of novel symbols will be used as stimuli. The aim of the current experiment is to determine if the increase in equivalence-consistent responding observed in the previous experiment will be maintained during Colour Test conditions with the second stimulus set.

Method

Participants and participant Identification

The same five participants who took part in Experiment 5 also participated in the current experiment.

Stimuli and Setting

All participants were trained and tested in identical settings to those used in Experiment 5 of the current chapter. The stimuli used in the present experiment comprised a new set of novel symbols. This second set of stimuli resemble the first set used in the prior experiments and were again presented in bold print on white laminated paper sized 8cm by 8cm squared. However, the symbols on the card were different from those used in the previous chapter and participants had not been exposed to them in previous experiments. The set of stimuli is represented in Figure 17.

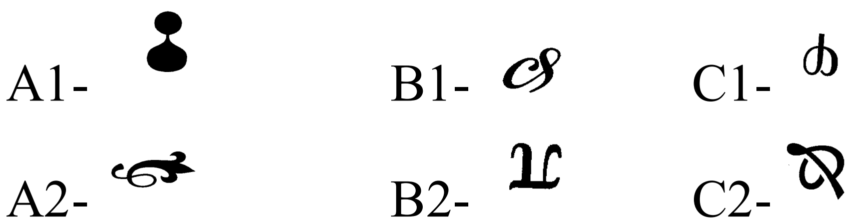

Figure 17. Symbols used as second set of stimuli (Again alphanumerics were not visible to the participants) .

Reinforcers

The reinforcement procedures and schedules used in the present experiment were identical to those used in *Experiment 5* of the present chapter.

Procedure

Participants were first exposed to a MTS training and testing procedure with the second set of novel symbols. The procedures used were identical to those in Phase 2 of Experiments 2 and 4 where participants were exposed to both blocked training and mixed training conditions with stimuli coloured only black until they demonstrated criterion performance levels. Participants then proceeded to the equivalence testing conditions, which were identical to Experiments 2 and 4.

Results

The data for the number of training trials and number of equivalence-consistent responses produced by all participants is presented in Table 9. All five participants achieved the target criterion during training and qualified for equivalence testing, with the number of training exposures required to achieve criterion ranging from fifteen exposures (P1) to one exposure (P6). When participants were exposed to the *Colour Test* condition, three of them maintained equivalence-consistent responding, but two did not (P2 & P6), although in the case of P6 the failure was by

Table 9. Number of training trials and number of correct responses during test blocks using black stimuli in Experiment 6:

Exp#		P 1	P 2	P 4	P 5	P 6
No Colour1	**Second Novel Stimulus set**					
1	Train	50	56	63	57	
	Test	-------	17/20	8/20	17/20	
2	Train	58	58	60		
	Test	------	16/20	13/20		
3	Train	54	55	56		
	Test	4/20	17/20	15/20		
4	Train	57		51		
	Test	4/20		17/20		
5	Train	50		51		
	Test	4/20		17/20		
6	Train	48				
	Test	4/20				
7	Train	56				
	Test	5/20				
8	Train	51				
	Test	12/20				
9	Train	50				
	Test	11/20				
10	Train	48				
	Test	15/20				
11	Train	48				
	Test	10/20				
12	Train	48				
	Test	10/20				
13	Train	49				
	Test	10/20				
14	Train	48				
	Test	15/20				
	Train	48	59	48	52	52
	Test	**19/20**	**18/20**	**18/20**	**19/20**	**20/20**
Colour Test	Train	55	51	49	48	58
	Test	**19/20**	**14/20**	**18/20**	**20/20**	**17/20**
No Colour2	Train	48	52	48	48	48
	Test	**20/20**	**17/20**	**20/20**	**20/20**	**19/20**

only one response. When the participants were returned to training and testing with all black stimuli, the equivalence-consistent responding was maintained by the three successful participants. For the two who failed, their equivalence responding improved, with P2 failing to reach criterion by only one response.

The data for numbers of errors made by participants in the *Colour Test* conditions are presented in Table 10. P5 was omitted from this table because he made no error responses in the *Colour Test* condition. Of the four participants who produced error responses in the *Colour Test* condition, three made both colour matching and neutral error responses, while P1 only produced one neutral error.

Table 10. Number of error responses and number of colour matching errors during Colour Test condition for all participants.

Participant	Number of errors during *Colour Test* condition	Number of colour response errors during *Colour Test* condition
1	1	0
2	6	3
4	2	1
6	3	2

Discussion

All participants in the current experiment produced criterion levels of equivalence- consistent responding during the *No Colour* conditions with a second stimulus set. Most importantly, three of the five participants maintained criterion levels of equivalence responding during the *Colour Test* condition. Two participants (P2 and P6) demonstrated weaker equivalence-consistent responding in the *Colour Test* condition relative to the two *No Colour* conditions.

The data from Experiment 6 indicate that exposing participants to a single exemplar that involved training and testing with coloured stimuli subsequently undermined the interference effect with a novel stimulus set. As noted above, however, two participants continued to show some evidence of colour-interference. In the next experiment, therefore, these two participants were exposed to a second exemplar of colour training and testing, followed by exposure to a third novel stimulus set with all black training followed by colour testing.

Experiment 7

Introduction

In Part 1 of the current experiment, participants were exposed to colour training and testing with the second novel stimulus set (used in Experiment 6). In Part 2, participants were then exposed to a third novel stimulus set, with training and testing with all black stimuli, followed by testing with coloured stimuli. Would the two previous “colour-ignoring” exemplars across Experiments 5 and 6 of the current chapter facilitate criterion test performances?

Method

Participants and participant Identification

The participant population employed in the current experiment comprised the two participants from Experiment 6 who failed to produce criterion test performances when they were trained with black stimuli but tested with colour stimuli.

Stimuli and Setting

The experiment was carried out in identical settings to those used in previous experiments in the current chapter. In Part 1, the second stimulus set of novel symbols was used. In Part 2 a third stimulus set was used (see Figure 18).

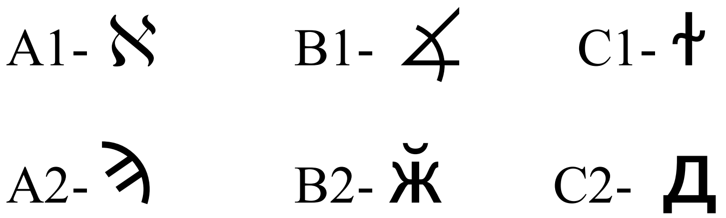

Figure 18. Third stimulus set of symbols used in Part 2 of Experiment 7. Note that participants were not exposed to the alphanumeric labels, which are used here for communicative purposes.

Reinforcers

The reinforcement procedures and schedules used in both parts of the current experiment were identical to those used with the same participants in previous experiments in the current chapter.

Procedure

The current experiment took place across two parts.

*Part 1 – Colour Training with second stimulus set.*The participants were exposed to a MTS training and testing procedure with coloured stimuli identical to that used in Experiment 6 of the current chapter.

Part 2 – Training and testing with third stimulus set. Participants were exposed to a MTS procedure identical to that used in Experiment 6. However, in the current experiment a third stimulus set was used. Participants received MTS training with black stimuli before being tested with coloured stimuli.

Results

The results for Part 1 of the experiment are shown in Table 11. Both participants achieved criterion levels of arbitrary relational responding in the training conditions, but P2 required four exposures to achieve criterion and qualify for testing. Both participants achieved criterion levels of equivalence-consistent responding in the *Colour Test 1* condition, with P2 requiring three exposures to reach the criterion target while P6 required two exposures. Both participants maintained criterion levels of equivalence-consistent responding in the *No Colour* and *Colour Test 2* conditions. The participants made no errors during the *Colour Test* conditions.

Table 11. Number of training trials and number of correct responses during Part 1 of Experiment 7:

Exp#		P 2	P 5
Colour Test 1	**Part 1 -Second Set**		
1	Train	70	56
	Test	-------	17/20
2	Train	66	
	Test	------	
3	Train	77	
	Test	-------	
4	Train	66	
	Test	16/20	
5	Train	51	
	Test	17/20	
6	Train	48	51
	Test	**20/20**	**20/20**
No Colour	Train	51	48
	Test	**19/20**	**20/20**
Colour Test 2	Train	48	48
	Test	**20/20**	**20/20**

The results for Part 2 are presented in Table 12. Both participants achieved criterion during training on their first exposure and qualified for testing. P2 condition while P6 required three training and testing exposures to reach criterion.

P6 maintained criterion levels of equivalence-consistent responding during the *Colour Test* and *No Colour 2* conditions. P2, however, failed to achieve criterion by one error response during the *Colour Test* condition.

Table 12. Number of training trials and number of correct responses during test blocks using third stimulus set coloured black:

Exp#		P 2	P 5
No Colour1	**Part 2 – Third Set**		
1	Train	52	60
	Test	12/20	9/20
2	Train	51	51
	Test	10/20	17/20
3	Train	50	
	Test	14/20	
4	Train	48	
	Test	15/20	
5	Train	48	
	Test	16/20	
6	Train	48	
	Test	13/20	
7	Train	49	
	Test	17/20	
8	Train	49	50
	Test	**18/20**	**19/20**
Colour Test	Train	48	48
	Test	**17/20**	**20/20**
No Colour2	Train	48	48
	Test	**20/20**	**20/20**

Discussion

During Part 1 both participants demonstrated criterion levels of equivalence-consistent responding in the Colour Test conditions with stimulus set two. However, P2 required a number of exposures to achieve the target criterion during training and a further number of training and testing exposures to produce criterion levels of equivalence-consistent responding in the *Colour Test 1* condition. This suggests that, for P2, the presence of a competing non-arbitrary colour relation was interfering with the emergence of equivalence class formation. P6 did not require the same number of training and testing exposures to produce criterion levels of equivalence-consistent responding.

In Part 2 P6 maintained criterion levels of equivalence-consistent responding during the *Colour Test* condition with the novel stimulus set (i.e., without colour training). P2 failed to maintain criterion levels of equivalence-consistent responding during the *Colour Test* condition, but only by one error response. Given that P2 had increased the number of equivalence-consistent responses across each stimulus set (i.e., 9, 14, 17), only failed by one response in the last exposure, and had participated for months in the experiment research programme it was decided to terminate his participation at this stage.

General Discussion

The experiments that made up the current chapter investigated the effectiveness of exemplar training with coloured stimuli in increasing levels of equivalence-consistent responding for children with a diagnosis of autism. The results of Experiment 6 demonstrated the effectiveness of colour training *within* a stimulus set for all five participants. That is, they demonstrated equivalence-consistent responding in the presence of a non-arbitrary colour relation. Three participants then continued to produce equivalence-consistent responding with a novel stimulus set in the absence of colour training. The two remaining participants (P2 and P6) required exposure to two exemplars of training and testing with colour before producing performances on a novel stimulus set that met (P6), or almost met (P2), criterion.

The current results suggest that exemplar training was effective in undermining the non-arbitrary stimulus control that served to disrupt the formation of equivalence classes for five of the participants. This finding is generally consistent with previous research that has shown exemplar training to be effective in generating derived relational responding in children (Barnes-Holmes, Barnes-Holmes, Roche & Smeets, 2001; Luciano, Barnes-Holmes & Barnes-Holmes 2001; Luciano et. al 2007, Barnes-Holmes, Barnes-Holmes, Strand, Smeets & Friman, 2004; Barnes-Holmes, Barnes-Holmes & Smeets, 2004). On balance, however, it must be recognised that the Experiments reported in the current chapter did not employ a formal experimental design, and thus it is not possible to conclude with certainty that the exemplar training was responsible for the improvements observed. For example, perhaps the improvements observed in the current experiment were simply the result of natural maturational and/or educational processes. Of course, it would be highly coincidental that all five participants demonstrated more or less the same levels of improvement on the targeted behaviours, and thus an important role for exemplar training seems likely if not certain.

One option at this point in the research programme would have been to conduct a formal experiment that would test the role of exemplar training in undermining non-arbitrary stimulus control in equivalence class formation. However, at this stage it was deemed important to explore the role of a second dimension of non-arbitrary stimulus control. In the natural environment there are possibly many different dimensions of non-arbitrary stimuli that could, in principle, interfere with arbitrary stimulus control. For example, shape (as well as colour) could provide the basis for non-arbitrary relational responding, and thus it is important to determine if undermining non-arbitrary stimulus control for one stimulus dimension transfers or generalises to a second dimension. The experiments reported in the next two chapters begin this work.

Chapter 6

CHAPTER 6:

Undermining Competing Non-Arbitrary Stimulus Control Across Stimulus Dimensions I: Colour to Shape

The experiments in Chapter 5 demonstrated that it is possible to undermine stimulus control for competing non-arbitrary colour relations. Recent research into the effectiveness of exemplar training has shown that if a specific pattern of relational responding is established with one or more sets of stimuli, that pattern may generalise to novel stimulus sets (Barnes-Holmes, Barnes-Holmes, Smeets, Strand & Friman, 2004; Barnes-Holmes, Barnes-Holmes & Smeets, 2004; Gomez, Lopez, Martin, Barnes-Holmes & Barnes-Holmes, 2007; Luciano, Berccera & Valverde, 2007; Berens & Hayes 2007). The experiments that make up the current chapter will seek to determine if introducing a dimension of competing non-arbitrary stimulus control, other than colour, will interfere with equivalence class formation in a population of children diagnosed with autism. The purpose of the first experiment was to determine if the learning to “ignore” colour in the previous experiments would facilitate the demonstration of equivalence class formation in the presence of another form of non-arbitrary stimulus control, in this case shape. The second experiment increased the level of potential non-arbitrary stimulus control by presenting participants with an equivalence test containing competing colour *and* shape stimulus dimensions.

Experiment 8

Introduction

In this first experiment, participants were trained using black symbols but during testing the symbol stimuli were surrounded by a shape, either a circle or a triangle. Would the participants' experience of ignoring colour across multiple exemplars in the previous chapter facilitate equivalence class formation in the presence of a competing non-arbitrary shape relation?

Method

Participants and Participant Identification

Four of the five participants employed in the experiments presented in the previous chapter took part in the current experiment. P2 from the previous experiment did not participate. There were three males and one female participant and their ages ranged from 6 - 8 years.

Stimuli and Setting

All participants took part in identical settings to those described in the experiments presented in previous chapters. The stimuli used in the present experiment comprised a fourth stimulus set of novel symbols (See Figure 19).

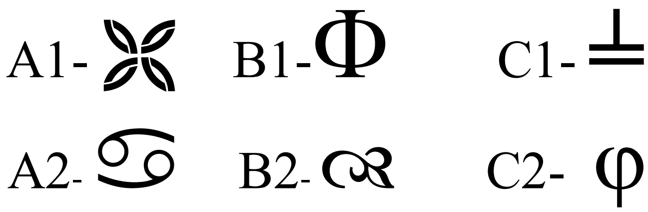

Figure 19. Fourth stimulus set of symbols used in Experiment 8.

During the training phases of the current experiment all stimuli were presented as black symbols on white cards. However, during the test condition the stimuli appeared surrounded by a shape (referred to as the *Shape Test* condition). The shape was either a circle or a triangle and appeared in black on the white card surrounding the symbol (See Figure 20).

Figure 20. Fourth stimulus set of symbols during the shape testing condition.

Reinforcers

The reinforcement procedures and schedules used in the present experiment were identical to those used with the same participants in the experiments presented in Chapter 5. All participants received access to reinforcing items of their own choice and received reinforcement on a schedule that matched the schedules of reinforcement of a typical school day.

Procedure

Training procedures: The training procedures used were identical to those used in Experiment 6 of Chapter 5 except that the fourth (novel) stimulus set was used. All stimuli used during training were coloured black and were not surrounded by any shape.

Equivalence testing procedures: When participants demonstrated the target criterion during training they proceeded to an equivalence testing phase with no shapes surrounding the stimuli, referred to as the *No Shape 1* condition. Participants were required to demonstrate a criterion level of equivalence-consistent responding in this condition prior to advancing to the other testing conditions. If a participant failed to demonstrate criterion during the *No Shape 1* condition they were recycled through training and testing until criterion was achieved.

Following the *No Shape 1* condition participants was re-exposed to another cycle of training followed by the *Shape Test* condition, where each stimulus was surrounded by a shape. The shape surrounding each stimulus was coloured black and was either a circle or a triangle. Shape was assigned to the stimuli such that one of the comparisons was always the same shape as the sample stimulus whereas the other comparison was a different shape. The correct comparison stimulus was a different shape to the sample stimulus in 70% of presentations but was the same shape as the sample stimulus in 30% of presentations. This ensured that consistently matching or mismatching shapes alone would fail to produce a criterion level equivalence performance (see Figure 21). After the *Shape Test* condition was completed, participants were recycled through one more exposure of training and testing with non-shape stimuli, referred to as the *No Shape 2* condition.

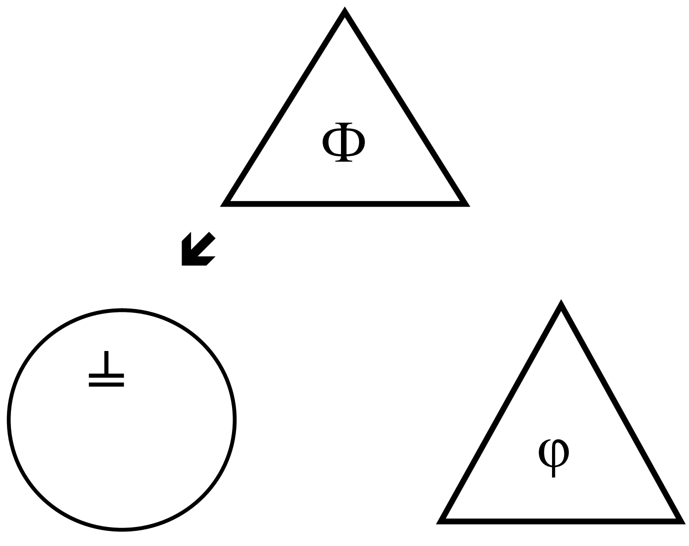

Figure 21. Shape-Test condition with competing non-arbitrary relation of shape.

Results and Discussion

The data for the training and testing exposures for each participant are presented in Table 13. All four participants demonstrated criterion levels of arbitrary relational responding during training and qualified for testing. P1 and P6 produced criterion levels of equivalence responding in their first testing exposure (*No Shape 1* condition). P5 required three training exposures to qualify while P4 required two training exposures.

P4 demonstrated criterion equivalence-consistent responding following one unsuccessful training exposure and two subsequent training and testing exposures. P5 required two unsuccessful training exposures followed by four training and testing cycles to produce criterion levels of equivalence-consistent responding.

Table 13. Number of training trials and number of correct responses during test blocks using fourth stimulus set:

Exp#		P 1	P 4	P 5	P 6
No Shape1	**Fourth Stimulus Set**				
1	Train		52	59	
	Test		-------	-------	
2	Train		51	55	
	Test		12/20	------	
3	Train			61	
	Test			17/20	
4	Train			50	
	Test			9/20	
5	Train			49	
	Test			12/20	
6	Train	53	48	48	73
	Test	**20/20**	**20/20**	**20/20**	**19/20**
Shape Test	Train	49	48	48	60
	Test	**20/20**	**18/20**	**18/20**	**20/20**
No Shape2	Train	48	49	48	48
	Test	**20/20**	**18/20**	**20/20**	**20/20**

All four participants maintained criterion levels of equivalence-consistent responding during the *Shape Test* and *No Shape 2* conditions, thus demonstrating that the introduction of shapes had no impact on their equivalence test performances. In the next experiment the participants were exposed to a test condition in which both competing shape *and* colour non-arbitrary stimulus relations were introduced into the equivalence test.

Experiment 9

Introduction

The current experiment exposed participants to the same stimulus set and identical training procedures as were used in Experiment 8 of the current chapter. However, during testing participants were exposed to two sources of competing non-arbitrary stimulus control.

Method

Participants and participant Identification

Three of the four participants from Experiment 8 took part in the current experiment (P4 was unavailable). The participants were three males between the ages of 6 and 8 years.

Stimuli and Setting

All participants were trained and tested in identical settings to those used in Experiment 8. The stimuli used in the present experiment comprised the fourth set of novel symbols that were also used in Experiment 8. The stimuli were black and were not surrounded by a shape during the training phases and during the *No Shape/Colour* testing conditions. However, during the *Shape/ Colour Test* condition the stimuli were coloured either red or green and were also surrounded by a shape, either a circle or a triangle (See Figure 22).

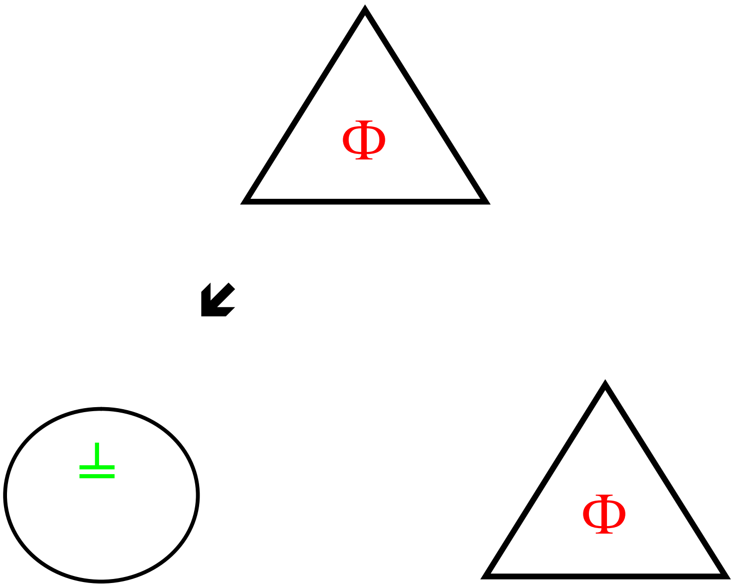

Figure. 22: Shape/Colour Test condition with fourth stimulus set.

Reinforcers

The reinforcement procedures and schedules used in the present experiment were identical to those used in Experiment 8.

Procedure

Training procedures: The training procedures used in the present experiment were identical to those used in Experiment 8.

Equivalence testing procedure: The equivalence test procedures for the *No Shape Colour 1* and *No Shape Colour 2* conditions in the current experiment were identical to those used in Experiment 8. However, in the current experiment participants were exposed to a *Shape/Colour Test* condition where the stimuli were surrounded by a shape (either circle or triangle) *and* were coloured either red or green. In the *Shape/Colour Test* condition shape and colour were assigned to the stimuli such that the correct comparison stimulus was a different shape and colour to the sample stimulus in 70% of presentations but was of the same shape and colour as the sample stimulus in 30% of presentations. This ensured that consistently matching or mismatching according to either shape and/or colour would fail to produce a criterion level training performance.

Results and Discussion

The data for the number of training trials and number of equivalence-consistent responses produced by all participants is presented in Table 14. All three participants achieved the target criterion during training on their first exposure and qualified for equivalence testing. All the participants also demonstrated criterion levels of equivalence-consistent responding in the *No Shape/Colour 1* condition during their first exposure. Two of the participants (P1 and P6) maintained criterion levels of equivalence-consistent responding during both the *Shape/Colour Test* and *No Shape/Colour 2* conditions. However, P4 failed to maintain criterion levels of equivalence-consistent responding in either the *Shape/Colour Test* or the *No Shape/Colour 2* conditions, although in the case of the *No Shape/Colour 2* condition, the failure was by only one response. Thus, two of the three participants continued to maintain equivalence responding, even when two non-arbitrary stimulus dimensions were introduced into the test. For one participant, however, the introduction of both shape and colour undermined a test performance which had been emitted reliably across numerous previous exposures.

Table 14. Number of training trials and number of correct responses during test blocks in Experiment 9:

Exp#		P 1	P 4	P 6
	Fourth Novel Stimulus set			
No Shape Colour1	Train	48	49	48
	Test	**20/20**	**18/20**	**20/20**
Shape Colour Test	Train	48	48	48
	Test	**20/20**	**8/20**	**19/20**
No Shape Colour2	Train	48	52	48
	Test	**18/20**	**17/20**	**19/20**

General Discussion

The experiments that make up the current chapter demonstrated that, for these participants, the introduction of a second dimension of competing non-arbitrary stimulus control (shape) did not interfere with equivalence class formation. The results of Experiment 8 demonstrated that receiving colour training across a number of exemplars in previous experiments facilitated the participants in maintaining equivalence-consistent responding in the presence of a competing non-arbitrary shape relation. Two participants also maintained criterion levels of equivalence-consistent responding in Experiment 9, suggesting that these participants had learned to “ignore” multiple forms of non-arbitrary stimulus control (i.e., shape and colour), even when these competing sources of control occurred simultaneously.

P4 failed to maintain criterion levels of equivalence-consistent responding during the *Shape/Colour Test* condition even though he had previously demonstrated equivalence class formation across a variety of stimulus sets in the presence of one source of competing non-arbitrary stimulus control. In this case, the introduction of a second competing stimulus dimension interfered with equivalence class formation.

One potential criticism of the experiments presented in the current chapter concerns the stimulus dimension of shape. This dimension is external to the symbol stimulus (i.e., the shape surrounds the symbol), and thus altering the shape alters the area surrounding the symbol rather than the symbol itself. Altering the stimulus dimension of colour, however, alters the appearance of the symbol itself and, as such, the colour stimulus dimension is intrinsic to the stimulus. Perhaps, therefore, colour training provides a relatively effective learning history for "ignoring" irrelevant non-arbitrary stimulus relations. Would such prior training with shape, rather than colour, provide a similarly effective learning history? Given that all of the participants in the previous experiments first experienced multiple exposures to colour training before the introduction of shape the question remains unanswered. In the next experiment, therefore, experimentally naïve participants (with autism) were exposed to shape training before the introduction of colour as the irrelevant non-arbitrary stimulus dimension.

Chapter 7

CHAPTER 7

Undermining Competing Non-Arbitrary Stimulus Control Across Stimulus Dimensions II:

Shape to Colour.

Initially the experiments that make up the current chapter will investigate if a competing non-arbitrary shape relation would disrupt equivalence class formation. Two new participants will be exposed to similar MTS procedures to those used in previous chapters whereby participants receive training and testing with stimuli without a competing non-arbitrary stimulus relation before being tested in the presence of a competing non-arbitrary shape relation.

If a competing non-arbitrary shape relation disrupts equivalence class formation participants will be exposed to shape training procedures across a number of exemplars until criterion levels of equivalence-consistent responding are achieved. This experiment investigates whether shape training across a number of exemplars would serve to remediate any disruption of equivalence responding due to the presence of a competing shape response.

The final experiment seeks to replicate the findings of Experiment 8 in Chapter 6, which demonstrated that colour training across a number of exemplars also taught participants to ignore the stimulus dimension of shape when it competed with equivalence-consistent responding. In the current experiment, however, the participants received prior shape training and were then exposed to a test condition with a competing non-arbitrary colour relation.

Experiment 10

Introduction

This experiment exposed two new participants to MTS training procedures identical to those used in Chapters 3 and 4. However, during the test conditions of the current experiment all participants were initially tested with stimuli that were not surrounded by a shape prior to being exposed to a test condition with a competing non-arbitrary shape relation. The aim of the experiment was to examine if a competing non-arbitrary shape relations would disrupt equivalence class formation.

Method

Participants and participant identification

The participants were two male children with a diagnosis of autism. Their ages ranged from six to seven years. Both participants were enrolled in ABACAS Schools with participant 1 enrolled in the ABACAS School, Drogheda while participant 2 attended the ABACAS School, Kilbarrack. Both schools provide autism specific education to children with autism through the use of applied behaviour analysis.

Stimuli and Setting

All participants took part in identical settings to those described in the experiments presented in previous chapters. Two sets of stimuli were used in the current experiment. In Phase 1 the same stimulus set of familiar symbols used in Chapters 3 and 4 were presented to the participants (see Figure 12 in Chapter 3 for an example of the stimuli).

In Phase 2 the fourth stimulus set of novel symbols were used (See figure 19). During training all stimuli were presented as black symbols on white cards. However, during the *Shape Test* condition the stimuli appeared surrounded by a shape. The procedures and criteria were identical to those used in Experiment 8 of Chapter 6.

Reinforcers

The reinforcement procedures were identical to those used with participants in previous chapters. That is, the schedules of reinforcement and choice of reinforcing items were individualised to the needs and preferences of each participant.

Procedure

The experiment was conducted over several sessions with each child. Sessions lasted approximately 20 minutes, but no longer than 30 minutes. Testing phases were always conducted immediately after the participant had reached the appropriate training criteria.

Phase 1: Initial training and testing during familiarisation condition. All participants were exposed to an initial training and testing condition in which a stimulus set comprising symbols representing common objects was used. This condition was identical to Phase 1 of Experiment 3. After the participant achieved a criterion level of equivalence-consistent responding in this Phase they advanced to Phase 2 of the experiment.

Phase 2: Full training and testing with fourth stimulus set. The training and testing procedures used in Phase 2 were identical to those used in Experiment 8 of Chapter 6. That is, participants were trained and tested with stimuli that were not surrounded by a shape prior to the introduction of a competing non-arbitrary shape relation during testing (i.e., the *Shape Test* condition).

Results and Discussion

The data for the training and testing exposures for each participant are presented in Table 15. Both participants demonstrated equivalence class formation in Phase 1 with the stimulus set of familiar symbols. P2 achieved criterion after one exposure while P1 required three exposures to achieve criterion.

Table 15. Number of training trials and number of correct responses during test blocks for each participant:

Training and Test Blocks		Participant 1	Participant 2
Familiarisation Condition	Phase 1		
1	Train	56	52
	Test	-------	**20/20**
2	Train	49	
	Test	15/20	
3	Train	48	
	Test	**20/20**	
No Shape 1	Phase 2		
1	Train	53	54
	Test	-------	---------
2	Train	37	52
	Test	-------	-------
3	Train	53	54
	Test	-------	16/20
4	Train	48	48
	Test	11/20	15/20
5	Train	55	53
	Test	14/20	16/20
6	Train	50	50
	Test	17/20	17/20
7	Train	51	51
	Test	**20/20**	**18/20**
Shape Test	Train	48	48
	Test	**7/20**	**5/20**
No Shape2	Train	48	64
	Test	**17/20**	**18/20**

During Phase 2, P1 required three training exposures to demonstrate criterion levels of arbitrary relational responding but qualified for all subsequent test conditions. P1 demonstrated criterion equivalence-consistent responding in the *No Shape 1* condition after four further training and testing conditions. P2 required two training exposures to achieve criterion levels of arbitrary relational responding during training but qualified for all subsequent testing conditions. P2 achieved criterion levels of equivalence-consistent responding after five further training and testing exposures.

Both participants failed to maintain criterion levels of equivalence-consistent responding during the *Shape Test* condition with both demonstrating below chance levels of responding. Both participants produced robust levels of equivalence in the *No Shape 2* condition with P2 maintaining criterion levels of responding and P1 only failed by one response.

Error analysis: Table 16 presents the total number of errors made by each participant in the *Shape Test* condition, and the number of those errors that involved matching a comparison stimulus that was the same shape as the sample stimulus (i.e., shape-matching). The majority of errors involved shape-matching. P1 produced eight shape matching errors and five neutral errors while P2 produced thirteen shape matching errors and two neutral errors.

Table 16. Number of error responses and number of shape matching errors during *Shape Test* condition.

Participant	Number of errors during Shape Test condition	Number of shape response errors during Shape Test condition
1	13	8
2	15	13

Overall, therefore, the current findings showed that both participants demonstrated equivalence class formation across both the known and novel sets of stimuli when there was no competing shape relation. However, during the *Shape Test* condition both participants produced far lower levels of equivalence-consistent responding. These results replicate the disruptive effect of competing non-arbitrary colour relations on equivalence class formation reported in previous chapters. An effective intervention used in previous experiments for reducing such interference was colour training across a number of exemplars. The following experiment will thus investigate the effectiveness of shape training in reducing the interference of competing non-arbitrary shape relations.

Experiment 11

Introduction

The current experiment exposed participants to a MTS training procedure with shape surrounding the stimuli. The aim of this experiment was to examine the effect of being explicitly taught to "ignore" shape before being tested for equivalence class formation in the presence of a competing non-arbitrary shape relation.

Method

Participants and Participant Identification

Both participants from Experiment 10 participated in the current experiment.

Stimuli and Setting

All participants took part in the present experiment in identical settings to Experiment 10. The stimuli used in the present experiment comprised the fourth set of novel symbols used in Experiment 10. In the present experiment, however, the stimuli were presented surrounded by a shape during the training phases of the experiment and during the *Shape Test* conditions. All stimuli were surrounded by a circle or a triangle.

Reinforcers

The reinforcement procedures and schedules used in the present experiment were identical to those used with the same participants in Experiment 10.

Procedure

Training procedures: The procedures used in the present experiment are similar to those used in Experiment 5 of Chapter 5. However, in the current experiment participants received training with stimuli surrounded by shape rather than with the coloured stimuli. All stimuli used during the training phases were surrounded by either a triangle or a circle (See Figure 21). Shape was assigned to the stimuli such that one of the comparisons was always the same shape as the sample stimulus whereas the other was a different shape. The correct comparison stimulus was a different shape to the sample stimulus in 70% of presentations but was of the same shape as the sample stimulus in 30% of presentations. This ensured that consistently matching or mismatching shapes alone would fail to produce a criterion level training performance. Once criterion was achieved participants advanced to testing.

Equivalence testing procedure: In the current experiment participants were required to demonstrate criterion levels of equivalence responding in testing conditions with stimuli surrounded by a shape (i.e., the *Shape Test* 1 condition). If a participant failed to demonstrate criterion levels of equivalence responding during the *Shape Test* 1 condition they were recycled through training and testing with shape stimuli until criterion was achieved.

When a participant achieved criterion levels of equivalence-consistent responding they were then re-exposed to shape training followed by a testing condition with non-shape stimuli (i.e., the *No Shape* condition). After the *No Shape* condition participants were recycled through one more exposure of training and testing with shape stimuli (the *Shape Test 2* condition).

Results and Discussion

Table 17. Number of training trials and number of correct responses during test blocks in Experiment 11:

Exp#		P 1	P 2
Shape Test1	**Fourth Stimulus Set**		
1	Train	55	57
	Test	11/20	9/20
2	Train	53	48
	Test	14/20	17/20
3	Train	49	48
	Test	15/20	17/20
4	Train	52	48
	Test	17/20	**20/20**
5	Train	48	
	Test	**20/20**	
No Shape	Train	48	49
	Test	**20/20**	**20/20**
Shape Test2	Train	48	48
	Test	**18/20**	**20/20**

The data for the training and testing exposures for each participant are presented in Table 17. Both participants achieved criterion levels of arbitrary relational responding in the training phase on their first exposure and qualified for testing. P1 required require five training and testing exposures to produce criterion levels of equivalence-consistent responding in the *Shape Test 1* condition. P2 required four training and testing exposures. Both participants maintained criterion levels of equivalence-consistent responding in the *No Shape* condition and the *Shape Test 2* condition.

Training with stimuli surrounded by shapes was effective in disrupting the competing non-arbitrary stimulus control. The next experiment will expose the participants to a novel set of stimuli in order to determine if undermining the competing non-arbitrary stimulus control by shape will generalise to anther stimulus set.

Experiment 12

Introduction

The current experiment will expose participants to an identical MTS training and testing procedure as was used in Experiment 10. However, a new set of novel symbols will be used as stimuli. The aim of the current experiment is to determine if the increase in equivalence-consistent responding observed in the previous experiment will be maintained during the *Shape Test* condition with the novel stimulus set.

Method

Participants and participant Identification

The same two participants employed in Experiment 11 also participated in the current experiment.

Stimuli and Setting

All participants took part in the present experiment in identical settings to the previous experiments in the current chapter. The stimuli used in the present experiment comprised a fifth set of novel symbols (see Figure 23) which were presented without any shape surrounding them during training but during the *Shape Test* condition they were either surrounded by a triangle or a circle.

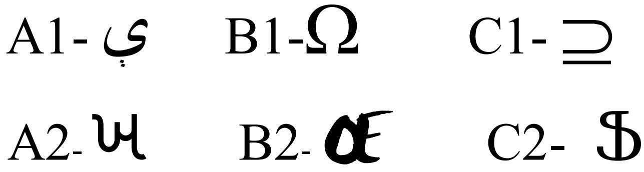

Figure. 23: Fifth stimulus set of symbols used in Experiment 12.

Reinforcers

The reinforcement procedures and schedules used in the present experiment were identical to those used in previous experiments in the present chapter.

Procedure

Participants were exposed to a MTS training and testing procedure identical to that used in Experiment 10 with the exception that a fifth set of novel symbols were used.

Results

The data for the training and equivalence test conditions in the present experiment are presented in Table 18. P1 achieved the target training criterion and qualified for testing on his first exposure. He required seven training and testing exposures to demonstrate criterion levels of equivalence-consistent responding in the *No Shape* 1 condition. P2 failed to achieve the target training criterion on his first exposure but qualified for testing on all subsequent exposures, producing a criterion level equivalence performance after 3 further cycles of training and testing.

Both participants maintained criterion levels of equivalence consistent responding in the *Shape Test* condition. P1 also maintained criterion in the *No Shape* 2 condition but P2 failed to achieve criterion by one error response. This result replicates the findings of the experiments in Chapter 5, where training with coloured stimuli across a number of exemplars was effective in undermining stimulus control across the non-arbitrary stimulus dimension of colour. However, the two participants in the current experiment only required shape training across one exemplar to facilitate equivalence class formation in the presence of a competing shape relation. The next experiment will examine if the participants' experience of "ignoring" the stimulus dimension of shape will undermine the non-arbitrary dimension of colour as a source of competing stimulus control.

Table 18. Number of training trials and number of correct responses during test blocks in Experiment 12:

Exp#		P 1	P 2
No Shape1	**Fifth Novel Stimulus set**		
1	Train	56	53
	Test	6/20	-------
2	Train	52	48
	Test	14/20	10/20
3	Train	56	49
	Test	13/20	16/20
4	Train	49	48
	Test	4/20	**18/20**
5	Train	50	
	Test	17/20	
6	Train	52	
	Test	17/20	
7	Train	48	
	Test	**19/20**	
Shape Test	Train	48	48
	Test	**18/20**	**19/20**
No Shape2	Train	48	48
	Test	**17/20**	**20/20**

Experiment 13

Introduction

The aim of the current experiment was to determine if a competing non-arbitrary colour relation would interfere with equivalence-consistent responding. Participants were trained using black symbols but during testing the symbol stimuli were coloured, either red or green. Would the participants' experience of "ignoring" shape in the previous experiment facilitate equivalence class formation in the presence of a competing non-arbitrary colour relation?

Method

Participants and Participant Identification

The same two participants who took part in the previous experiments were also employed in the current experiment.

Stimuli and Setting

All participants took part in identical settings to those described in the previous experiments presented in the current chapter. The stimuli used in the present experiment comprised stimulus set 1 of novel symbols employed in chapters 3 and 4 (see figure 13). The current participants had not previously been exposed to this stimulus set. During the training phases of the current experiment all stimuli were presented as black symbols on white cards. However, the stimuli were coloured either red or green during the *Colour Test* condition.

Reinforcers

The reinforcement procedures and schedules used in the present experiment were identical to those used in previous experiments in the present chapter.

Procedure

Participants were exposed to a MTS training and testing procedure identical to that used in Experiment 5. However, in the current experiment the first stimulus set of novel symbols were used. Participants were trained and tested using stimuli coloured black before being exposed to the *Colour Test* condition where stimuli were coloured either red or green.

Results and Discussion

Table 19 shows the data for the training and testing exposures for both participants. Each participant demonstrated criterion levels of arbitrary relational responding during training and qualified for testing on their first exposure. P1 required four training and testing exposures to achieve criterion levels of equivalence-consistent responding during the *No Colour* 1 condition. P2 required three training and testing exposures.

P1 maintained criterion levels of equivalence-consistent responding during the *Colour Test* and *No Colour* 2 conditions. P2 failed to maintain criterion levels of equivalence consistent responding during the *Colour Test* condition, but only failed by one error response. P2 returned to criterion levels of equivalence-consistent responding during the *No Colour 2* condition. In effect, both participants largely maintained the levels of equivalence-consistent responding that they produced in the previous experiment. This suggests that the experience of “ignoring” the stimulus dimension of shape also taught the participants to ignore the novel stimulus dimension of colour.

Table 19. Number of training trials and number of correct responses during test blocks in Experiment 13:

Exp#		P 1	P 2
No Colour1	**First Stimulus Set**		
1	Train	71	61
	Test	7/20	10/20
2	Train	56	48
	Test	13/20	17/20
3	Train	48	48
	Test	13/20	**19/20**
4	Train	49	
	Test	**19/20**	
Colour Test	Train	48	48
	Test	**19/20**	**17/20**
No Colour2	Train	48	48
	Test	**19/20**	**19/20**

General Discussion

The participants in the current chapter demonstrated a similar pattern of responding to the pattern observed in previous chapters with participants initially presented with a competing non-arbitrary colour relation. The results of Experiment 10 demonstrated that the presence of a competing shape relation disrupted equivalence-consistent responding replicating the disruptive effect of a competing colour relation reported in previous experiments. In Experiment 11, participants were exposed to a shape training procedure to undermine the disruptive effect of non-arbitrary stimulus control. Both participants achieved criterion levels of equivalence-consistent responding during the *Shape Test* conditions of this experiment and maintained criterion equivalence-consistent responding in Experiment 12 with a new set of novel stimuli. Both participants required only one exemplar of shape training to demonstrate equivalence class formation in the presence of a competing shape relation. This result illustrates the effectiveness of shape training in reducing the interference effect of competing non-arbitrary stimulus control.

Previous experiments in the current thesis had reported that training to ignore the stimulus dimension of colour had readily facilitated participants in maintaining equivalence-consistent responding in the presence of other forms of competing non-arbitrary stimulus control. Experiment 13 demonstrated that shape training facilitated participants in producing equivalence-consistent responding in the presence of a competing non-arbitrary colour relation. Overall, therefore, the results of the experiments in the current chapter provide support for the findings reported in previous chapters of the current thesis. That is, children with autism show relatively high levels of disruption by non-arbitrary stimulus relations in forming equivalence classes, but this disruptive effect may be overcome with appropriate exemplar training.

Chapter 8

Chapter 8

General Discussion

The experiments presented in the current thesis extend the work of Stewart et al. (2002) who reported that competing non-arbitrary stimulus relations disrupted the formation of derived relational responding in adult participants. Specifically, the Stewart et al. (2002) study reported that participants who were trained with black stimuli but tested with colour (the Colour-Test group) produced lower levels of equivalence-consistent responding than participants in other groups. This disruption was not observed in the All-Colour group who were trained and tested with coloured stimuli. The research reported in the current thesis sought to explore experimental histories, in particular exemplar training, which would undermine competing non-arbitrary stimulus control in the context of an equivalence test. This research was conducted with adult, normally-developing children and children with a diagnosis of autism. In addition it was argued in Chapter 1 of the current thesis that the Colour-Test procedures developed by Stewart et al. (2002) may provide a methodology for the study of the behavioural processes involved in what cognitive psychologists refer to as executive function (EF). The purpose of the current chapter is to summarise and review the findings of the experiments that make up the current thesis.

Summary of Results

Adults. The *experiment* reported in Chapter 2 of the current thesis sought to extend the work of Stewart et al (2002) by further investigating the effects of differing training histories with regard to colour on equivalence class formation in the presence of a competing non-arbitrary colour relation. Participants were divided into groups, with two groups receiving training with coloured stimuli and two receiving training with stimuli coloured black (All Colour groups and Colour Test groups). Additionally, however, the experiment sought to examine the effectiveness of exemplar training in facilitating equivalence class formation. The groups were also divided, therefore, according to whether they received exemplar training or whether they were simply exposed to repeat test conditions (Repeat groups and Exemplar groups). As such, participants were divided across four groups; *Exemplar All Colour*, *Repeat All Colour*, *Exemplar Colour Test,* and *Repeat Colour Test.*

Consistent with Stewart, et al. (2002), the results of the experiment showed that groups trained with black stimuli but tested with colour showed lower equivalence-consistent responding than those groups trained with coloured stimuli. In addition, the *Exemplar All Colour* group produced the highest levels of equivalence responding while the *Repeat Colour Test* group produced the lowest levels. The participants in the former group demonstrated consistent increases in equivalence responding across each set of stimuli, producing near errorless responding on the second and third sets. Interestingly, the exemplar training was less effective when it was combined with all black stimuli (*Exemplar Colour Test*), but it still produced higher levels of equivalence-consistent responding than when no exemplar training was provided (*Repeat Colour Test)*. Finally, when training with colour stimuli was provided without exemplars (*Repeat All Colour*), performances improved to almost the same levels as when exemplar training was included, although improvement across the stimulus sets was less dramatic without the exemplar training.

The data for both the *Exemplar* and *Repeat Colour Test* groups showed they continued to produce "colour matching" errors across the three stimulus sets. While the *Exemplar Colour Test* group showed reductions in non-arbitrary error responding in the second exposure of each set, levels of colour matching returned to lower levels in exposure one of each set. Colour matching errors remained consistently high across all test exposure for the *Repeat Colour Test* group. The data for both All Colour groups showed decreasing levels of errors across all test exposures.

Overall, therefore, the experiment replicated the findings of Stewart et al. (2002), but also demonstrated that training with colour across a number of exemplars produced the most rapid improvement in equivalence-consistent responding. In contrast, the two conditions that trained with black stimuli failed to produce any clear evidence of undermining colour as a competing source of non-arbitrary stimulus control. Even when participants were trained to produce equivalence-consistent responding on one set of stimuli (*Exemplar Colour Test*), the improved performance did not generalise to a subsequent novel stimulus set. Thus, training with colour stimuli appeared to be critical in undermining non-arbitrary stimulus control in an equivalence test, although including exemplar training served to facilitate relatively rapid improvement across sets.

Normally-Developing Children: The Experiment 2 presented in Chapter 3 sought to examine the effect of a competing non-arbitrary stimulus relation on equivalence class formation in a participant population of normally developing young children. This experiment used a table-top MTS procedure derived from the work reported in Chapter 2, which was modified for use with a younger population. It was also deemed important to demonstrate that the children could form equivalence classes before the introduction of a test involving competing non-arbitrary stimulus relations. Otherwise, failure during the latter critical test might be due to a general failure to form equivalence relations rather than being attributed to interference from non-arbitrary colour relations. Thus the children were first required to demonstrate equivalence class formation with a stimulus set of familiar stimuli. Furthermore, the children were also required to demonstrate equivalence-consistent responding with the novel stimulus set when it was presented in black during training and testing. Only then were they exposed to this novel stimulus set in black during training, but in colour during the critical equivalence test. This procedure provided an extremely conservative methodology for examining the disruptive effect of colour as a source of competing non-arbitrary stimulus control, because participants were first required to demonstrate equivalence responding with the stimuli in black before they were presented in colour.

Interestingly, all four normally-developing children in this experiment demonstrated equivalence class formation with black stimuli and critically maintained equivalence responding when the stimuli were presented with competing non-arbitrary colour relations. For these participants, therefore, the introduction of a competing source of non-arbitrary stimulus control did not interfere with equivalence class formation. The results presented in this chapter thus provided a firm basis on which to explore the impact of non-arbitrary stimulus relations on equivalence responding with children diagnosed with autism. Insofar as this population suffer from poor executive function, and interference by non-arbitrary stimuli is an indicative deficit in this regard, it was predicted that children with autism would show greater evidence of such interference relative to the normally developing children. The remaining experiments in the thesis focused exclusively on this issue.

Children Diagnosed with Autism. Experiment 3 of Chapter 4 sought to determine if the procedures used in the previous chapter facilitated the robust acquisition of equivalence and completely undermined subsequent non-arbitrary stimulus control. As such, one participant diagnosed with autism was exposed to a reduced procedure where there was no requirement to demonstrate equivalence class formation with black stimuli and the familiar stimulus set was not presented. The participant was also cycled through two exposures of training and testing to determine if equivalence responding would improve over repeat presentations. The results showed that the participant failed to demonstrate equivalence class formation in any of the test conditions and showed a lower level of equivalence performance in Exposure 2 relative to Exposure 1. While the participant's equivalence performance was lower in the *Colour Test* condition relative to other conditions, it should be noted that there were high levels of neutral errors in all conditions. This result suggested that facilitating the emergence of equivalence with all black stimuli prior to the introduction of colour is essential if the impact of non-arbitrary stimulus control is to be analyzed independently of the non-formation of equivalence classes due to "neutral" errors.

Experiment 4 of Chapter 4 exposed six participants diagnosed with autism to procedures identical to those reported in Chapter 3. The results showed that all six participants demonstrated equivalence class formation with both the familiar stimuli and the novel stimulus set coloured black. This result clearly demonstrated that the procedures were effective in facilitating the emergence of equivalence class formation in children diagnosed with autism. Interestingly, however, five of the six participants failed to show equivalence class formation in the *Colour Test* condition and produced high levels of "colour matching" errors. This result contrasts sharply with the results reported for age-matched normative children in Chapter 3 and provide clear evidence that children diagnosed with autism are far more susceptible than normally-developing peers to the disruption of equivalence responding by competing non-arbitrary stimulus control. However, one participant maintained equivalence-consistent responding in the *Colour Test* condition of Experiment 4, suggesting that children diagnosed with autism may not always succumb to non-arbitrary stimulus control. The experiments presented in Chapter 5 sought to determine if colour training procedures derived from those reported in Chapter 2 would be effective in undermining the observed disruption from competing non-arbitrary stimulus relations in children diagnosed with autism.

In Experiment 5 of Chapter 5 the five participants who failed to maintain equivalence responding in the previous chapter were exposed to *training* with coloured stimuli. All participants subsequently demonstrated equivalence class formation when tested with the same coloured stimuli. The aim of Experiment 6 was to determine if the undermining of non-arbitrary stimulus control with one stimulus set (i.e., set 1) would facilitate participants in maintaining equivalence with a novel stimulus set (i.e., set 2). This experiment exposed participants to a second set of novel stimuli using procedures identical to Experiment 4 (i.e., training and testing with all black stimuli and then testing with the same stimuli in colour). In effect, participants were not trained using Set 2 coloured stimuli prior to the *Colour Test* condition. The results showed that three of the five participants maintained criterion levels of equivalence-consistent responding in the *Colour Test* condition, but two did not. The result for the three successful participants suggested that the undermining of non-arbitrary stimulus control following colour training with Set 1 had also undermined colour as a source of competing stimulus control with Set 2. This outcome is consistent with the results observed for the *All Colour* groups in Experiment 2 who showed rapid increases in equivalence responding across stimulus sets following training with coloured stimuli. Finally, it should be noted that the two unsuccessful participants produced higher levels of equivalence-consistent responding than was evident with Set 1 in Chapter 4. Indeed, one participant only failed to achieve criterion by one error response.

In Experiment 7 in this chapter the two unsuccessful participants from Experiment 6 were exposed to colour training with the second stimulus set before being trained and tested using a third stimulus set with black stimuli and then tested in colour. One participant demonstrated equivalence class formation in the *Colour Test* condition, while one participant failed to achieve criterion by only one error. Taken together, the results of the experiments presented in Chapter 5 suggested that training with colour undermined competing non-arbitrary stimulus control both within and across stimulus sets. In other words, the effects of colour training in undermining non-arbitrary stimulus control with one stimulus set generalised to subsequent stimulus sets.

The experiments presented in Chapter 6 sought to determine if undermining non-arbitrary stimulus control following exemplars of colour training would also serve to undermine other competing sources of non-arbitrary stimulus control (in this case shape). Experiment 8 employed four participants who had successfully demonstrated equivalence responding in the *Colour Test* conditions in the previous chapter. Specifically, they were trained and tested with a novel stimulus set, all presented in black, until they demonstrated equivalence class formation. Subsequently, the children were exposed to the equivalence test they had previously passed, but the stimuli were presented surrounded by shapes (i.e., *Shape Test* condition). Results showed that all four participants maintained equivalence-consistent responding during testing when a competing shape relation was present. In effect, participants who had not received explicit shape training successfully "ignored" shape as a source of competing non-arbitrary stimulus control, thus showing that the effects of colour training had generalised both within and across stimulus dimensions.

Experiment 9 exposed three participants from the previous experiment to a test condition with two forms of competing non-arbitrary stimulus control (colour and shape). Interestingly, results showed that two participants maintained equivalence class formation in these conditions. One participant failed to maintain criterion, however, despite having produced equivalence responding in the presence of each of the two dimensions when presented individually.

As suggested above, one interpretation of the results reported in Chapter 6 is that the stimulus dimension of shape did not disrupt equivalence formation because the impact of colour training generalized to the shape. However, it is possible that the shape stimuli simply had a less disruptive impact than the introduction of colour, and thus generalisation played little or no role in the observed performances with shape. The experiments presented in Chapter 7 sought to address this criticism by introducing competing shape relations in experimentally *naïve* participants diagnosed with autism (with no prior colour training or testing). The results of Experiment 10 showed that two naïve participants demonstrated equivalence class formation in the absence of shape relations but failed to maintain equivalence when shape was introduced during testing. The majority of errors made by participants consisted of "shape matching" errors. Thus, it appeared that the introduction of competing shape relations disrupted equivalence responding similar to competing colour relations in previous chapters.

Experiment 11 extended this work by exposing participants to a shape training procedure using the same stimuli as the previous experiment but the stimuli were surrounded by a shape. Both participants readily demonstrated equivalence class formation in the presence of a competing shape relation, which again was consistent with the results observed in Experiment 5, where disruption from competing non-arbitrary colour relations was undermined following colour training. Experiment 12 further extended the research by exposing participants to training and testing with a new novel stimulus set in the absence of shape relations before introducing a competing shape relation during testing. Results showed that participants maintained equivalence in the presence of a competing shape relation with a novel stimulus set. The results from these two experiments showed that shape training with one stimulus set facilitated equivalence-consistent responding across a second stimulus set without explicit shape training. Once again, this was consistent with the results reported in previous chapters where exemplars of colour training were shown to undermine colour as a source of competing stimulus control across novel stimulus sets.

The final Experiment 13 in Chapter 7 sought to replicate the previously reported finding that explicit training to "ignore" one source of competing non-arbitrary stimulus control was effective in maintaining equivalence in the presence of another competing stimulus dimension. A new stimulus set of novel stimuli were used and the two participants were trained and tested with black stimuli until they demonstrated equivalence class formation. When a competing colour relation was then introduced during the *Colour Test* condition, results showed the maintenance of equivalence-consistent responding, with one participant failing to reach criterion by only one error response. This finding showed that equivalence-consistent responding established in the presence of competing shape relations generalised to competing colour relations (i.e., without any prior colour training). This result contrasts with the clear disruption of equivalence by competing colour relations reported in Experiment 4 of Chapter 4. Overall, therefore, prior exposure to colour training and testing generalised to the shape dimension (Chapter 4) and prior shape training and testing generalised to the colour dimension (Chapter 7).

Discussion of Chapters 2 and 3

The experiment presented in Chapter 2 reported results consistent with Stewart et al. (2002) and showed that the presence of a competing non-arbitrary colour relation disrupted equivalence class formation in adult participants. This is consistent with past research showing that competing sources of stimulus control can disrupt derived relational responding (Watt, Keenan, Barnes, & Cairns, 1991; Leslie, Tierney, Robinson, Keenan, Watt & Barnes, 1993; Barnes, Lawlor, Smeets & Roche, 1996; Merwin & Wilson, 2005; Dixon, Rehfeldt, Zlomke & Robinson, 2006). Critically, in the context of the current thesis, the results reported in Chapter 2 also showed that explicit training with coloured stimuli facilitated the emergence of equivalence class formation in the presence of competing non-arbitrary colour relations. The findings indicate that it is possible to remediate the disruption of equivalence-consistent responding reported by Stewart et al. (2002).

Interestingly, when participants were explicitly trained to produce equivalence responding without colour training (*Exemplar Colour Test* condition), this did not produce equivalence-consistent responding on subsequent stimulus sets. Thus training with coloured stimuli appeared to be the critical variable in undermining non-arbitrary stimulus control in an equivalence test. The fact that explicit equivalence training alone did not lead to equivalence-consistent responding is inconsistent with previous research that has demonstrated the effectiveness of exemplar training in establishing derived relational responding (Barnes-Holmes, Barnes-Holmes, Roche & Smeets, 2001; Barnes-Holmes, Barnes-Holmes, Smeets, Strand & Friman, 2004; Barnes-Holmes, Barnes-Holmes, & Smeets 2004, Berens & Hayes, 2007). On balance, participants in the current experiment were exposed to only two exemplars and these were presented within a single session. Perhaps additional exemplars spread across multiple sessions would have undermined the non-arbitrary stimulus control. Future experiments might explore this issue further.

In the experiment conducted with adults the participants were not required to demonstrate equivalence responding before introducing competing non-arbitrary colour relations. Thus, it is possible that some of the participants who failed the equivalence tests would have done so even if colour relations were not introduced. A more conservative test of the impact of competing colour relations would require participants to demonstrate equivalence responding before proceeding to the critical colour test condition. The experiment presented in Chapter 3 adopted this approach with normally developing children. In addition, past research has with children indicates that the use of familiar stimuli facilitates the training of conditional discriminations and production of equivalence (O Connor, Rafferty, Barnes-Holmes & Barnes-Holmes, 2009), and thus this strategy was also employed. The near perfect equivalence performances observed in the context of competing colour relations indicated that the modified procedures were highly effective. At the current time it is not possible to determine exactly what modifications to the procedures were responsible for producing such robust equivalence responding in the children compared to the adults in the previous experiment. Once again, this could be an interesting avenue for future research.

Discussion of Chapter 4

Experiment 3 in Chapter 4 presented a participant diagnosed with autism with a reduced training procedure (i.e., no requirement to demonstrate equivalence class formation with black stimuli and the familiar stimulus set was not presented). This participant failed to demonstrate equivalence-consistent responding in all test conditions, but when six participants diagnosed with autism were exposed to full training and testing procedures (Experiment 4) they all demonstrated equivalence class formation with stimuli coloured black. However, critically five of the six participants failed to maintain equivalence-consistent responding when a competing colour relation was introduced during testing. This result contrasts with the findings reported for age-matched normative children in the Chapter 3, and indicates that children diagnosed with autism are more vulnerable to the disruption of derived relational responding by non-arbitrary stimulus relations.

Interestingly, the foregoing finding is consistent with studies reporting poor performance by children with autism in Executive Function (EF) tasks such as the Tower of Hanoi (Ozonff, Pennington & Rogers, 1991; Hughes, Russell & Roberts, 1994; Benneto et al. 1996), Pennington & Rogers, 1991; Hughes, Russell & Roberts, 1994; Benneto et al. 1996), Tower of London (Pennington & Ozonoff, 1996, Ozonoff & Jenson, 1999; see Hill, 2004 for review), and the WCST (i.e., see Ozonff 1997 for review of previous studies). As discussed in Chapter 1, these tasks require children to combine working memory and inhibitory control to withhold "proponent" responses by maintaining a conflicting response rule in memory (Diamond, 1990; Diamond, Prevor, Callendar, & Druin, 1997; Roberts & Pennington, 1996; Joseph, Mc Grath, & Tager-Flusberg, 2005). In the context of the current thesis, the five unsuccessful participants showed a clear deficit in inhibiting the "proponent" colour matching response which disrupted pre-established equivalence-consistent responding demonstrated with black stimuli. The perseverative pattern of colour matching is also consistent with previous research reporting that children diagnosed with autism demonstrate perseverative and rigid patterns of responding (Turner, 1999, McEvoy, Rogers & Pennington, 1993). Overall, therefore, the current data support the argument offered in the introductory chapter that presenting competing arbitrary and non-arbitrary stimulus relations in an equivalence test may provide a behaviour-analytic test of so called executive function. As noted previously, however, the behaviour-analytic approach is primarily concerned with influencing as well as predicting behaviour, and thus efforts need to be made to improve deficits in executive function, which brings us to the next two chapters.

Discussion of Chapters 5 and 6

The results of Experiment 5 in Chapter 5 demonstrated that colour training with the first stimulus set facilitated all participants in maintaining equivalence-consistent responding in the colour test with that set. In Experiment 6, three of the five participants also demonstrated equivalence-consistent responding in the colour test condition with the second stimulus set. When the two unsuccessful participants were exposed to another exemplar of colour training in Experiment 7 they subsequently demonstrated equivalence-consistent responding with a another novel stimulus set. These results are consistent with previous studies reporting that explicit training across exemplars was effective in undermining autism-specific deficits in derived relational responding (O Toole, Barnes-Holmes, Murphy, O Connor & Barnes-Holmes, 2009; Murphy, Barnes-Holmes & Barnes-Holmes, 2005). They also provide support for the findings reported in Chapter 2 of the present thesis that colour training across exemplars undermined spurious non-arbitrary stimulus control. The finding that equivalence-consistent responding increased following colour training across a small number of exemplars is also largely in keeping with the literature on the use of exemplar training to establish relational responding (e.g., Barnes-Holmes, Barnes-Holmes, Roche & Smeets, 2001a, 2001b). However, it should be noted that all participants in the experiments presented in Chapter 5 had demonstrated equivalence class formation with stimuli coloured black prior to the introduction of colour. Thus colour training could be said to have established a behavioural history that undermined colour as a salient stimulus dimension for controlling responding on the equivalence tests.

This undermining effect was further explored in Experiment 8, which sought to determine if multiple exemplars of colour training would facilitate equivalence being maintained in the presence of other dimensions of competing non-arbitrary stimulus control (i.e., shape). Results showed that all participants readily demonstrated equivalence class formation in the presence of a competing shape relation, suggesting that explicit colour training undermined colour *and* shape as a source of competing control. Experiment 9 then exposed participants to a *Colour/Shape Test* condition where there two sources of competing control. Two participants continued to demonstrate equivalence responding, but one did not. The generalisation of the training and testing with colour to the shape dimension is consistent with a recent study showing that exemplar training was effective in facilitating derived comparative relations and generalising them not only across stimulus sets but also across trial types (Berens & Hayes 2007). The fact that one participant failed to maintain equivalence responding when colour and shape were combined during the test is consistent with past research that has shown that autistic participants show increasing deficits in tests of EF as the complexity of the test is increased (Zelazo, 2004). Perhaps future research could explore further the role of increasing the number of competing stimulus dimensions in the context of equivalence tests, focusing in particular on populations with known deficits in executive function.

Discussion of Chapter 7

The experiments presented in Chapter 7 sought to determine if a competing shape relation would disrupt equivalence-consistent responding with a experimentally naïve participants (two children diagnosed with autism). Experiment 10 exposed participants to training and testing in the absence of shape prior to introducing a competing shape relation during testing. Results showed that participants demonstrated equivalence class formation in the absence of shape but failed to maintain equivalence when shape was introduced. This finding is consistent the results reported in Experiment 4 where the introduction of a competing colour relation was shown to disrupt equivalence-consistent responding in another population of children with autism. These findings indicates that the disruption of equivalence responding extends beyond competing colour relations to other stimulus dimensions. Perhaps future research could determine if the introduction of other sources of non-arbitrary stimulus control disrupts equivalence-consistent responding in the same manner observed for both shape and colour in the current research.

When participants were exposed to explicit shape training in Experiment 11 participants demonstrated equivalence-consistent responding in shape test conditions with the same stimulus set. Furthermore, in Experiment 12 participants also maintained equivalence-consistent responding when shape was introduced with a new set of novel stimuli. Taken together the results of these two experiments are consistent with the results reported in Chapter 5 where participants demonstrated the emergence of equivalence class formation following explicit colour training procedures. Overall, these findings are also consistent with results reported in previous experiments that found explicit training was effective in facilitating the emergence of derived relational responding and undermining spurious sources of stimulus control (O'Toole, Barnes-

Holmes, Murphy, O Connor & Barnes-Holmes, 2009; Murphy, Barnes-Holmes & Barnes-Holmes, 2005).

Experiment 13 exposed participants to training and testing with a new stimulus set coloured black. Participants were then exposed to a colour test condition where a competing colour relation was introduced. Participants demonstrated equivalence-consistent responding (one participant failed by one error response). This result replicated the finding reported in Experiment 8 where participants demonstrated equivalence-consistent responding in the presence of a competing shape relation following explicit colour training. Taken together, the results of both these experiments suggest that undermining one form of non-arbitrary stimulus control may serve to undermine multiple other sources of competing non-arbitrary stimulus control. Perhaps future research could systematically explore the extent to which explicit non-arbitrary stimulus training serves to undermine increasing sources of such stimulus control in the context of derived relational responding.

Conclusion

Although the results reported in the current thesis are relatively clear, on balance, it should be acknowledged that there are a number of potential weaknesses in the experimental procedures employed in the current thesis. As previously noted, many of the experiments did not employ a formal experimental design, which prevents firm conclusions being drawn with regard to certain findings. For example, a multiple baseline design could be employed to determine the exact role played by explicit training across exemplars in undermining sources of competing non-arbitrary stimulus control.

Another potential criticism of the current thesis is that unlike one of the adult groups in Chapter 2 (*Exemplar Colour Test*), the participants diagnosed with autism were never exposed to exemplars of explicit equivalence training with black stimuli. Past research has shown that explicit equivalence training has been effective in facilitating the emergence of equivalence class formation (e.g., Healy, Barnes-Holmes, & Smeets, 2000). It could be argued, therefore, that explicit equivalence training with black stimuli may have facilitated the emergence of more robust equivalence-consistent responding in colour test conditions with children diagnosed with autism. However, it should be noted that the *Exemplar Colour Test* group in Chapter 2 of the current thesis was exposed to explicit exemplar training with black stimuli, and it appeared to have little effect. Thus it seems unlikely that children with autism would show significant benefit from such explicit training. Nonetheless, it remains to be seen if many repeated exposures to explicit equivalence training would eventually undermine competing non-arbitrary stimulus control in both adults and children.

Another possible criticism of the current research is that no attempt was made to systematically compare performance on standard tests of executive function and performance on the equivalence tests with competing stimulus control. Thus, the extent to which the latter performance is indicative of a deficit in executive function remains to be fully tested. On balance, it should be recognised that the very definition of executive function remains unclear, and inconsistent results have been obtained across different tests of executive function (Griffith, Pennington, Wehner & Rogers, 1999). Thus, the general approach offered here should be seen as “bottom-up”, targeting a specific deficit in stimulus control, which will lead potentially to a relatively complete functional-analytic treatment of executive function itself. If this objective is fully realised, then the concept of executive function would itself become redundant. In effect, the concept of executive function was used in the current thesis simply to orient us towards a specific psychological domain.

The current thesis presents the first series of experiments designed to explore the effects of competing non-arbitrary stimulus relations on equivalence class formation in normally developing children and those diagnosed with autism. Furthermore, the present work constitutes the first attempt to develop a behaviour-analytic methodology for assessing, and perhaps treating, a behavioural deficit, which seems to be closely related to the cognitive concept of "poor executive function". As such, much of the research presented in the current thesis was exploratory in nature and aimed to develop a framework, and generate possible questions, that could be the subject of more formal experimental analyses in subsequent research. Overall, the current research has shown that the role of competing non-arbitrary stimulus relations is an important area for future research, and this area could play a central role in understanding deficits in so called executive function in children diagnosed with autism.

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